

... useful, up-to-date and insightful information during those early days and well beyond.
I am grateful to our readers for all the feedback, good and about the badges. *Professor Tim Cook, OM*

Robinson & Hall's How to Survive in Anaesthesia

Sixth Edition

William Fawcett
Olivia Dow
Judith Dinsmore

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A Guide for Trainees

Sixth Edition

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Foreword

It is a pleasure to write a foreword to *How to Survive in Anaesthesia, 6th Edition*. The book is now in its 6th edition and despite the 5th edition being much celebrated and winning BMA Anaesthesia book of the year award, it has been fully updated. It has two new editors, joining Professor Fawcett, including welcoming a trainee in Dr Olivia Dow. All chapters have been updated and revised and there are several new chapters including those on ultrasound, common regional blocks, emergency laparotomy and reducing risk. Importantly another new chapter offers thoroughly modern, apposite and on point information about 'how to be the best' (or perhaps more accurately 'how to be *your* best') and includes such diverse topics as understanding sustainable anaesthesia, how to survive the electronic patient record, similar advice on managing the training process and portfolio development and finally some advice on self-care. All are worthy and practical additions in the environment we now practise. The book is up to date, well supported by infographics and a valuable introduction to and aid for those just starting out in the field.

The book retains its chatty style and honesty. Indeed it is disarmingly so at points (mishaps chapter!), but overall this honesty regarding the joy, trials, pitfalls and success of anaesthesia is to be welcomed: it is good to learn from other's mistakes, in the hope we can reduce the number we in turn make ourselves. Despite the approachable style the book is grounded and emphasises a practical core content. *How to Survive in Anaesthesia* will be an enjoyable and easy read for all and a welcome companion to novice anaesthetists, anaesthetic associates, operating department practitioners and medical students.

Anaesthesia is a brilliant speciality. Few regret a decision to join the ranks – but the first few weeks and months can be among the most daunting and exhausting of a career. Access to *How to Survive in Anaesthesia* will provide useful, up-to-date and insightful information during those early days and well beyond. I congratulate the authors and encourage those reading to sit back, read and absorb the wisdom.

*Professor Tim Cook,
OBE, Consultant in Anaesthesia and
Intensive Care Medicine at Royal
United Hospitals Bath NHS Foundation Trust, and
Honorary Professor of Anaesthesia at the
University of Bristol.*

Preface to the Sixth Edition

We are sad to say goodbye to our two founding authors, Neville Robinson and George Hall. They have retired and we wish them both well. They have steered the book thus far and leave big shoes to fill and this book is named after them.

It is great to welcome two new authors, Judith Dinsmore and Olivia Dow. The book has been thoroughly revised with some new chapters on reducing risk, pharmacology, emergency laparotomy, ultrasound, chronic pain and 'how to be the best' (detailing aspects of self-care during demanding shift work, delivering green anaesthesia, the training process, preparing your portfolio, preparing for meetings and the electronic patient record), with other chapters completely rewritten. Throughout, we have retained the popular style of previous editions and emphasis on basic safe practice. The speciality is evolving; for example, many have moved away from nitrous oxide, suxamethonium and desflurane and embraced total intravenous anaesthesia and the use of ultrasound, particularly for ultrasound-guided blocks. The concept of perioperative medicine is embedded into our daily practice. The book reflects these transitions.

As in previous editions we aim to educate, enthuse and amuse, by producing an easy to read and informative text, packed with practical information to start your career.

Preface to the Fifth Edition

We have thoroughly revised the text for this edition and ensured that the book is up to date.

Six new chapters have been added which are relevant to the novice anaesthetist.

We have altered the layout of the book to now make four sections. Section 4 deals with the clinical work outside the operating theatre environment and includes an introduction to intensive care and perioperative medicine.

Our goal remains to write a text that will introduce the new trainee to safe anaesthetic practice. We hope that this small book will continue to educate, enthuse and amuse.

Preface to the Fourth Edition

We have updated the content for this edition and added one essential chapter. We wish to thank readers for their helpful comments, and hope that our ideal of assisting anaesthetic novices in providing safe anaesthetic skills and practice is still achieved.

William Fawcett has generously agreed to assist with authorship of the book and has provided the text with a new freshness. He has added some case studies to the clinical sections and has contributed to the content of the whole text.

Preface to the Third Edition

We have added two chapters in response to discussion with trainees who asked for examples of anaesthetic mishaps and help in assessing sick patients. The emphasis remains on providing an introductory text to safe clinical practice. We are grateful to our many colleagues, senior and junior, for their support and advice, particularly Neville Goodman.

Preface to the Second Edition

We are grateful for the many comments received about the contents and style of the first edition. We have taken the opportunity to decrease the size of the book to make it more of a 'pocket book' and we have revised the text and added two new chapters.

Our main aim remains to provide a concise readable text that will introduce the new trainee in anaesthesia to safe clinical practice. In addition, the contents of the book are applicable to many clinical aspects of the primary Fellowship examination of the Royal College of Anaesthetists.

Preface to the First Edition

If you are a trained anaesthetist, you should not be reading this. If you have just started anaesthesia, congratulations on your choice; you have joined the most interesting speciality in medicine which contains some of the most intelligent, well-adjusted consultants to be found in hospitals (we can think of at least two). In your first few weeks of anaesthesia you will be given much advice, some of which may even be good, and will be influenced by the current issues affecting the speciality. It is easy to believe that audit, high dependency units, acute pain teams, et cetera, are areas of essential knowledge for the newcomer. They are not.

They only become relevant when you are capable of conducting a safe anaesthetic. We hope that this short book will help trainees in the first year of anaesthesia by emphasising basic principles and key concepts. Full explanations have been left for 'proper' textbooks.

We thank the many trainees who over the years have kept us entertained, enthused, sometimes informed, occasionally frightened and whose ingenuity in devising new mistakes never ceased to amaze.

Abbreviations

A – Amplitude

A&E – Accident and Emergency

ABCD – Airway, Breathing, Circulation, Disability

ABG – Arterial Blood Gas

ACGO – Auxiliary Common Gas Outlet

ACS-NSQIP – American College of Surgeons National Surgical Quality Improvement Programme

AED – Automated External Defibrillator

AFI – Awake Fibreoptic Intubation

AKI – Acute Kidney Injury

ALS – Advanced Life Support

AMBU – AMBUTM Bag-Valve-Mask

APL – Adjustable Pressure-Limiting Valves

APTT – Activated Prothrombin Time

ASA – American Society of Anaesthesiologists

BCIS – Bone Cement Implantation Syndrome

BiPAP – Bi-level Positive Airway Pressure

BIS – Bispectral Index monitoring system

BJA – British Journal of Anaesthesia

BMI – Body Mass Index

BP – Blood Pressure

c – Velocity

CASP – Critical Appraisal Skill Programme

CDs – Controlled Drugs

CICO – Cannot Intubate Cannot Oxygenate

CK – Creatinine Kinase

CNS – Central Nervous System

CO – Cardiac Output

CO₂ – Carbon Dioxide

COPD	Chronic Obstructive Pulmonary Disease
CPAP	Continuous Positive Airways Pressure
CPD	Citrate, Phosphate and Dextrose
CPET	Cardiopulmonary Exercise Testing
CPR	Cardiopulmonary Resuscitation
CSA	Continuous Spinal Anaesthesia
CSE	combined spinal epidural
CSF	Cerebrospinal Fluid
CT	Computerised Tomography
CVP	Central Venous Pressure
CVS	Cardiovascular System
DOACs	Direct acting oral anticoagulants
DAS	Difficult Airway Society
DIC	Disseminated Intravascular Coagulation
DO ₂	Oxygen Delivery
DVT	deep vein thrombosis
EC	Excitation and Contraction
ECG	Electrocardiogram
ECMO	Extracorporeal Membrane Oxygenation
ECT	Electroconvulsive Therapy
EEG	Electroencephalogram
EMLA	Eutectic Mixture of Local Anaesthetics
ENT	Ear Nose and Throat
Entonox	A mixture of nitrous oxide and oxygen used for pain relief
EPR	Electronic Patient Record
ETCO ₂	End-Tidal Carbon Dioxide
ETO ₂	End-tidal Oxygen
ETT	Endotracheal Tube
EWS	Early Warning Score
FFP	Fresh Frozen Plasma

FiO ₂	– Fraction of Inspired Oxygen
FONA	– Front of Neck Access
FRC	– Functional Residual Capacity
GABA	– Gamma-aminobutyric acid
GGHM	– Gown, Gloves, Hat and Mask
GI	– Gastrointestinal
GP	– General Practitioner
HAS	– Human Albumin Solution
Hb	– haemoglobin
HDU	– High Dependency Unit
HES	– Hydroxyethyl Starch
HIV	– Human Immunodeficiency Virus
HR	– heart rate
HRAC	– High Risk Anaesthetic Clinic
ICU	– Intensive Care Unit
ID	– Identification
iGel	– A type of supraglottic airway device
IPPV	– intermittent positive pressure ventilation
IT	– Information Technology
kg	– Kilogram
kHz	– Kilohertz
l/min	– Litres per minute
LAST	– Local Anaesthetic Systemic Toxicity
LA	– Local Anaesthetics
LIDCO	– Lithium dilution cardiac output
LMA	– Laryngeal Mask Airway
MAC	– Minimum Alveolar Concentration
MAP	– Mean Arterial Pressure
M&E	– Measurement and Evaluation
MDT	– Multidisciplinary Team
MEWS	– Modified Early Warning Score

MH – Malignant Hyperthermia

MHRA – Medicines and Healthcare products Regulatory Agency

MHz – Megahertz

MIS – Minimally Invasive Surgery

MRI – Magnetic Resonance Imaging

NCA – Nurse-Controlled Analgesia

NCEPOD – National Confidential Enquiry into Patient Outcome and Death

NELA – National Emergency Laparotomy audit

NEWS – National Early Warning Score

NG – Nasogastric

NIBP – Non-invasive blood pressure

NICE – National Institute for Health and Care Excellence

NIST – Non-interchangeable Screw Thread

NMBDs – Neuromuscular Blocking Drugs

NPPV – Non-invasive Positive Pressure Ventilation

NR – Needle-Resistance

NS – Normal Saline

NSAIDs – Non-Steroidal Anti-Inflammatory Drugs

OBESE – Abbreviation to help anticipate patients with difficult mask ventilation: Obese, Bearded, Elderly (>55 years), Snorer, Edentulous

ODA – Operating Department Assistant

ODP – Operating Department Practitioner

OSA – Obstructive Sleep Apnoea

PACU – Post Anaesthesia Care unit

PCA – Patient-Controlled Analgesia

PCI – Percutaneous Coronary Intervention

PCEA – Patient-Controlled Epidural Analgesia

PCV – Pressure Control Ventilation

PEA – Pulseless Electrical Activity

PEEP – Positive End-Expiratory Pressure

PICC – Peripherally Inserted Central Catheter

POCUS – Point of care ultrasound

PONV	Postoperative Nausea and Vomiting
POSSUM	Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity
PT	Prothrombin Time
ROSC	Return of Spontaneous Circulation
ROTEM	Rotational Thromboelastometry
RSI	Rapid sequence induction
SAD	Supraglottic Airway Device
SAG-M	Saline, Adenine, Glucose and Mannitol
SaO ₂	Oxygen Saturation (arterial blood gas)
SAS	Surgical Apgar Score
SDM	Shared Decision Making
SIRS	Systemic Inflammatory Response Syndrome
SNRIs	Serotonin-norepinephrine reuptake inhibitors
SORT	Surgical Outcome Risk Tool
SOFA	Sequential Organ Failure Assessment
SpO ₂	Oxygen Saturation (pulse oximetry)
SV	stroke volume
TACO	Transfusion associated Circulatory Overload
TAP	Transversus Abdominis Plane
TEE	Transoesophageal echocardiography
TEG	Thromboelastography
TGC	Time gain compensation
THRIVE	Transnasal Humidified Rapid Insufflation Ventilatory Exchange
TIVA	Total Intravenous Anaesthesia
TM Joint	Temporomandibular Joint
TOF	Train-of-four
TRALI	Transfusion Related Acute Lung Injury
TRIM	Transfusion Related Immunomodulation
TTE	Transthoracic echocardiography
TURP	Transurethral Resection of the Prostate
ULBT	Upper Lip Bite Test

VC – Volume Control

VF – Ventricular Fibrillation

VLs – Video Laryngoscopes

VT – Ventricular Tachycardia

WHO – World Health Organization



Let's Start at the Very Beginning . . .

If you are starting as a trainee in anaesthesia with little knowledge of how operating theatres work, read this. If you understand the theatre environment, go to Chapter 1.

What You Need

You will need your ID badge, two black pens (one invariably runs out of ink or is borrowed), a stethoscope and a copy of this book. You may also need a card to log on to the hospital IT system with associated passwords.

Where to Go

You need to find the correct changing room, male or female, and change into theatre scrubs, hat and suitable footwear. Do not leave anything valuable in your clothes; lock it away or take it with you. A combination padlock is useful to have. Do not enter the wrong changing room 'by mistake' more than once. Do not borrow theatre shoes: the pair you take will belong to one of the senior surgeons, who will make your life a misery for the next few months when (s)he finds that they are missing. Face masks are usually unnecessary except in theatres in which a prosthesis is inserted, such as orthopaedics.

You will see staff wandering round the hospital and even local shops in theatre scrubs. One author even saw a person wearing theatre scrubs in an international airport. This is inappropriate, and you should change each time you leave the operating theatre.

How to Behave

You should be punctual, polite and pleasant to all theatre staff. As a new anaesthetic trainee you may feel near the bottom of the theatre hierarchy.

Key People in Theatres

In each operating theatre there is a scrub nurse and a runner, who is not scrubbed, who fetches instruments for the surgical team. There is usually a theatre sister in overall charge. In the United Kingdom, the anaesthetist always works with a trained assistant. They may be called an operating department practitioner (ODP), operating department assistant (ODA) or anaesthetic nurse. They will have undergone at least two years of training and are often skilled in resuscitation and trauma assessment. Watch carefully how they prepare for cases and listen to any advice they may give. Very few ODPs are unhelpful to new trainees and the best are outstanding. We have learnt much from experienced ODPs and value their knowledge, commitment and friendship.

The theatre manager is an important person, so introduce yourself and try to gain their support (see How to Behave). The theatre receptionist/secretary has to deal with the running of the theatres and is often very knowledgeable about the likes and dislikes of senior staff. Time spent in idle chat is usually time well spent.

Key People in Anaesthetic Departments

The most important person in the anaesthetic department is the secretary/administrator/rota organiser. You must not upset them – they can make your life miserable. Other people in the department, who think that they are important, include the college tutor, educational supervisors, module supervisors, clinical supervisors, mentors and the head of department. It is very difficult to find any consultant without a label. The longer the title, the less important the position.

You should not need to bother these people in the first few weeks. In many departments you will work with a few senior staff who will guide you gently through the basics of anaesthesia. They are chosen for their kindness, imperturbability and good humour in the presence of the chaos of your initial attempts at anaesthesia. It is their job to imprint safe anaesthetic practice into your receptive brain. You will remember them long after you have forgotten the name of the head of department.

Cleanliness and Sterility

Cleanliness is important for all theatre staff. Hands must be washed, or an alcohol handrub used, before and after touching patients. This boring ritual is necessary to minimise infections acquired in theatres.

The patient's skin should be cleaned with chlorhexidine 2% in isopropyl alcohol 70 per cent before the insertion of needles and cannulae. For central venous cannulation and neuraxial blockade the anaesthetist should adopt surgical sterility: gown, gloves, hat and mask (GGHM).

Controlled Drugs (CDs)

The supply and use of drugs that can cause dependency or abuse, such as opioids, benzodiazepines, ketamine and cocaine, is tightly controlled by law under The Misuse of Drugs Act. These drugs are kept in a locked cupboard, and when they are used you must:

- Sign the controlled drug register. This is countersigned by another qualified person (nurse/qualified ODP). Your signature confirms that the number of remaining ampoules is correct. The register requires you to sign for the doses supplied, administered and wasted.
- Record the amount of drug given to the patient on the anaesthetic chart.
- Return unopened ampoules to the locked cupboard.
- Not use the contents of an ampoule for more than one patient.
- Discard any drug not used, ideally in the presence of a third party.

Although these regulations may appear onerous, it is the law and it protects both you and others in the department, making misuse of these drugs difficult (but not impossible). Pharmacies perform audits to ensure that the CD book tallies with the drugs administered in theatres and will hold the anaesthetist accountable for any discrepancies. Rarely (but not impossibly), the police can be involved.

Consent/WHO Checklist

Anaesthesia is not overburdened with paperwork but there are two key documents that must be checked before surgery starts. The consent form, which gives details of the surgical procedure, must have been signed by the patient and witnessed by a member of the surgical team. The identity of the patient must be determined on the patient's name band to ensure that the right patient is in the right place for the right operation. If the operation has a left or right choice (e.g., limb surgery) the side should be marked by the surgeon on the ward.

The consent form must be signed by a competent person. Almost always, this is the patient including children once they reach the age of 16, when they are presumed in law to be competent – their parents cannot override consent or refusal from a competent 16/17-year-old. This is called Form 1. Sometimes Form 4 is used if the patient's capacity to consent to the proposed procedure or treatment is in doubt (e.g., dementia or confusion). This form should be used when the patient lacks capacity and should be completed by the professional doing the procedure, and the decision to proceed is in the patient's best interest.

All hospitals have adopted the WHO Surgical Safety Checklist, which aims to prevent wrong-site surgery and decrease surgical complications. Although most of the details are surgical, the anaesthetist is asked for the American Society of Anaesthesiologists (ASA) status of the patient (see Chapter 22) and if they have any concerns. The latter refers to medical, not personal, concerns so it is inappropriate to mention your doubts about the possible health hazards of your recent social life. All members of the theatre team are introduced by name and role, which is a rapid way of integrating new trainees.

Anaesthetic Charts

The anaesthetic chart is a contemporaneous record of what happened to the patient while they were your responsibility. It is a very important document that must be completed legibly, accurately and in appropriate detail. The chart may be analysed very closely in the future by the legal profession, who will emphasise any omissions, errors and illegibility. A scruffy chart with coffee stains creates a bad impression. Anaesthetic charts vary slightly from hospital to hospital but contain the following basic information:

- patient details
- preoperative assessment
- intraoperative management
- postoperative instructions

The chart should contain enough information so that another anaesthetist could give an identical anaesthetic from the information recorded. The advent of the electronic patient record (EPR) still requires detailed documentation, which in many cases is easier to undertake.

Enthusiasts

The senior anaesthetists who supervise your initial training will protect you from the more eccentric members of the profession. However, you will encounter enthusiasts who believe passionately that their anaesthetic techniques are superior to those of others. Three groups are easily recognised: regional anaesthesia enthusiasts (always needing the ultrasound machine), infusion enthusiasts (the more infusion pumps the better the anaesthetic) and technology enthusiasts (always using the latest equipment with many totally unnecessary

functions). They all have useful knowledge to impart but should be avoided until you can give a safe simple anaesthetic.

... When you read you begin with A-B-C (airway-breathing-circulation) so read on (with apologies to *The Sound of Music*).

Nuts and Bolts

The first section of this book deals with two fundamental aspects of anaesthetic practice: the airway and vascular access.

General anaesthesia has been summarised by the simple phrase: put up a drip, put down a tube and give plenty of oxygen. Although many anaesthetists resent this glib description of their work, it does have the virtue of emphasising the importance of venous cannulation and control of the airway, which are essential for the safe conduct of anaesthesia. Difficulties arise in anaesthesia when one of these fundamental areas is not secure, and if both fail then disaster is close at hand.

Therefore, in the first 10 chapters we concentrate on evaluation and control of the airway, the anaesthetic machine and circuits, basic anaesthetic monitoring, vascular access and the choice of intravenous fluids. We have not given detailed instructions on how to undertake the practical procedures.

There is no substitute for careful instruction from a senior anaesthetist as part of the anaesthetic procedure. At the start of training the application of physiology and pharmacology to anaesthesia is exciting, and knowledge of the equipment may seem mundane and even boring. It is imperative that you have a basic understanding of the equipment you use – failure to do so will put the patient at risk.

Evaluation of the Airway

Experienced anaesthetists teach that there are three fundamental aspects to safe anaesthetic practice: the airway, the airway and the airway. Unanticipated airway problems account for about 40 per cent of overall anaesthetic morbidity and mortality. Therefore, before embarking upon anaesthesia, the anaesthetist must attempt to answer several key questions.

- Can I ventilate the patient with an airway and mask?
- Can I use a laryngoscope easily and safely on this patient?
- Can I intubate this patient safely without hypoxia or aspiration of stomach contents occurring?
- If I predict difficulties, have I got all the equipment and help available to assist me to secure the airway and oxygenate the patient?

Tracheal intubation is now undertaken less often, mainly because of the advent of supraglottic airways. However, tracheal intubation remains the gold standard for airway management, control and protection. It may be required during the course of an anaesthetic or for the management of an unconscious patient. Careful airway assessment must be undertaken. This is carried out logically, as summarised in Box 1.1.

History

Any previous anaesthetic history must be obtained. Information about difficulties with tracheal intubation may be found in old anaesthetic records. Previous successful intubation is not an indicator of current ease (e.g., tumours may have progressed, or radiotherapy may have been administered). Some patients carry letters or wear MedicAlert

Box 1.1 Assessment of the airway

- History
- Symptoms
- Examination
 - anatomy and variants
 - medical conditions
 - specific assessment
 - Mallampati scoring system
 - thyromental distance
 - sternomental distance
 - other tests

Box 1.2 Medical features of difficult airway intubation

- Congenital: rare
- Acquired
 - trauma: fractures of mandible and cervical spine
 - infection: epiglottitis, dental or facial abscess
 - endocrine: thyroid enlargement, acromegaly, obesity
 - neoplasia: tongue, neck, mouth, radiotherapy
 - inflammatory: ankylosing spondylitis, rheumatoid arthritis, scarring from burns
 - pregnancy
 - other: obstructive sleep apnoea (OSA), difficult dentition, recent intubation (swelling)

bracelets stating their anaesthetic difficulties, while others with major problems know nothing about them. Ascertain whether the airway is potentially difficult by checking whether the patient has any of the medical and surgical conditions listed in Box 1.2.

Whenever possible, you will also want to review any previous anaesthetic charts.

Symptoms

Upper airway obstruction may be found in patients with stridor, dysphagia and hoarseness.

Examination and Clinical Tests

Normal Anatomy and Its Variants

Some patients appear anatomically normal and yet are difficult, or impossible, to intubate. These patients cause anaesthetists unexpected problems. We have had the occasional experience of casually starting an apparently normal laryngoscopy, only to have the sinking feeling associated with complete failure to see the larynx. It is much better to anticipate a difficulty than encounter one unexpectedly. Some anatomical factors that make airway control and intubation difficult are listed in Box 1.3.

Box 1.3 Anatomical features of difficult airway control and intubation

- Short immobile neck
- Full set of teeth, buck teeth, edentulous
- High arch palate
- Poor mouth opening – less than three fingers gap between upper and lower teeth
- Small mouth
- Receding mandible (may be hidden by a beard)
- Inability to sublux the jaw (forward protrusion of the lower incisors beyond the upper incisors)

Specific Assessment

Several clinical tests to assess the airway are in common use. None are reliable in predicting a difficult airway or intubation, and all should be used in combination as this provides a better overall assessment of the airway.

Modified Mallampati Scoring System

This predicts about 50 per cent of difficult intubations. The test can be performed with the patient in the upright or supine position. It is based upon the visibility of the pharyngeal structures with the mouth open as wide as possible (Figure 1.1). Patients are classified as follows:

- Grade 1: faucial pillars, soft palate and uvula visible
- Grade 2: faucial pillars, soft palate visible, but uvula masked by the base of the tongue
- Grade 3: soft palate only visible
- Grade 4: soft palate not visible

Patients in grades 3 and 4 are considered difficult to intubate, and those in grades 1 and 2 are considered feasible intubations. It is important to realise that this system is not infallible, and patients in grade 2 sometimes cannot be intubated. The use of this test as a single predictor has been shown to have a high sensitivity and negative predictive value. However, its sensitivity remains low. It is therefore important to utilise a combination of tests when performing an airway assessment.

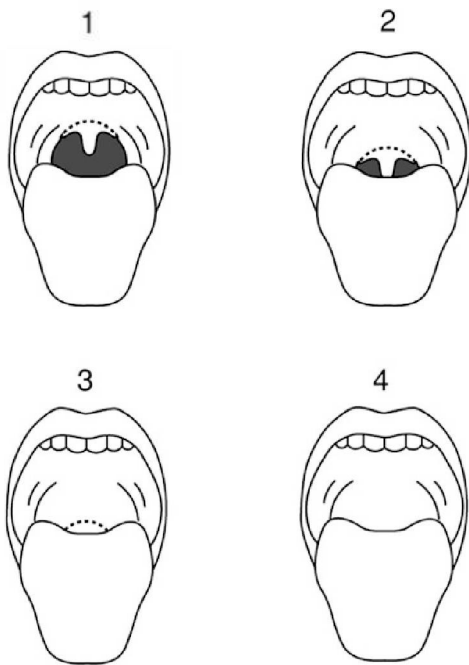


Figure 1.1 Structures seen on opening of mouth for Mallampati grades 1–4.

Head and Neck Movement

Flexion and extension are greater than 90° in normal people.

Jaw Movement and Mandible

Check that the patient's mouth opens normally. It should have an interincisor gap of greater than 5 cm (about three finger breadths). Check that the patient does not have buck teeth or a receding mandible. Ideally, the lower incisors should be able to be protruded beyond the upper incisors. If these simple tests cannot be performed the airway may be difficult to manage.

Thyromental Distance

The thyromental distance (Patil test) is the distance from the thyroid cartilage to the mental prominence when the neck is extended fully (Figure 1.2). In the absence of other anatomical factors, if the distance is more than 6.5 cm, problems should not occur with intubation. A distance of less than 6 cm suggests laryngoscopy will be impossible, and for distances of 6–6.5 cm laryngoscopy is considered difficult, but possible. This measurement may predict up to 75 per cent of difficult intubations.

Sternomental Distance

The distance from the upper border of the manubrium sterni to the tip of the chin, with the mouth closed and the head fully extended, is measured. A distance of less than 12.5 cm indicates a difficult intubation.

Upper Lip Bite Test (ULBT)

In this test, the patient is asked to bite his or her upper lip with the lower incisors. It has been shown to have good specificity and positive predictive value.

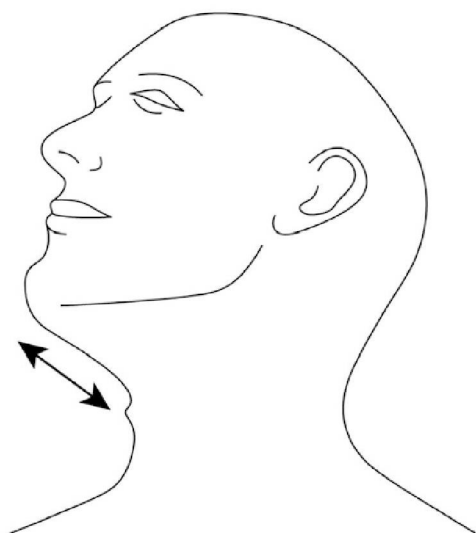


Figure 1.2 Line shows the thyromental distance from the thyroid cartilage to the tip of the chin.

Other Tests

Airways can be further assessed by using indirect laryngoscopy or imaging. Nasal endoscopy is frequently used to assess and grade difficult airways by passing a flexible scope via the nose to gain view of the glottis. This procedure is done in consented fully awake patients and the airway may be topicalised with local anaesthetic. Similarly, another approach includes the use of awake laryngoscopy also using a flexible scope or a videolaryngoscope. These methods have the benefit of allowing visualisation and dynamic assessment of the glottis and vocal cords.

Imaging methods include the use of lateral X-rays, which are less commonly used nowadays, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound.

Using X-rays, the effective mandibular length is compared with the posterior depth of the mandible; a ratio of more than 3.6 may be associated with a difficult intubation. A decreased distance between the occiput and the spinous process of C1 is also reported as associated with difficulties with laryngoscopy. We have found these tests to be of limited value.

Computed tomography imaging produces high-resolution views of the head, neck and chest, allowing a detailed assessment also including lower airway pathologies. The direct internal diameter of the tracheal lumen can be measured in the transverse plane and is particularly useful for stenotic tracheal lesions. Dynamic CT images (including inspiratory and expiratory phase) can be used to assess conditions that may cause dynamic airway collapse, such as tracheomalacia.

Ultrasound has become more widely accessible as a tool to detect the cricothyroid membrane used for front-of-neck access and also to predict difficult intubation and laryngoscopy.

To detect the cricothyroid membrane, a linear high-frequency transducer can be used in the transverse plane to determine the position of the trachea. This is then followed by a sagittal view scanning down from the hyoid bone to determine the location of the cricothyroid membrane. Moreover, the distance to the space can be noted and the patient's neck may be marked in case of an emergency. Sublingual ultrasound has been used to predict difficult intubation by visualising the hyoid bone. Similarly, the distances from the anterior skin to the epiglottis or hyoid bone have been used as predictors.

However, it must be remembered that clinical and radiological assessment modalities have limitations, as they do not account for dynamic airway changes related to posture and breathing.

Conclusion

The airway must be assessed before any anaesthetic procedure is embarked upon. Airway control and tracheal intubation is occasionally difficult, or even impossible, in anatomically normal people. An assessment of the patient's history, symptoms and medical conditions, combined with careful clinical examination, will help avoid many, but not all, unexpectedly difficult intubations. In addition, an airway may be physiologically difficult in a patient with physiological derangement or reduced oxygen reserve. This may lead to higher risk of hypoxaemia and complications and when combined with an anatomically difficult airway can easily become an anaesthetist's nightmare! A detailed preoperative assessment, preoxygenation and a well-prepared airway management plan are therefore a must.

Control of the Airway

The novice anaesthetist must learn the skills of airway control rapidly.

Position

The patient must be correctly positioned. This is achieved by elevating the head by about the height of a pillow to flex the neck. The head is extended on the cervical spine and the mandible lifted forward to stop obstruction from the tongue and other pharyngeal structures that lose their tone under anaesthesia. This position is commonly referred to as 'sniffing the early morning air' – a practice not to be recommended in a modern urban environment.

Methods

Four methods of airway control are used to ensure unobstructed gaseous exchange (Box 2.1).

Face Mask

The mask is designed to fit snugly over the patient's nose and mouth. However, gas often leaks around the side of the mask in edentulous patients. Clear masks allow you to see the airway and any secretions or vomit. Newer masks have inflatable rims that allow air to be added or removed from the mask to improve the tightness of the seal. An obstructed airway may be relieved by inserting an oropharyngeal airway (Guedel airway) or a nasopharyngeal airway. Guedel airways are sized from 0 to 4, with a size 3 used for adult females and 4 for adult males. Nasopharyngeal airways, unless they are inserted very gently, can cause haemorrhage, which may further threaten the airway. Difficult mask ventilation occurs in about 5 per cent of patients. The mnemonic OBESE (Obese, Bearded, Elderly (> 55 years!), Snorer and Edentulous) may help to anticipate these patients.

Supraglottic Airway Device (SAD): The Laryngeal Mask Airway and the iGel

The laryngeal mask airway (LMA) was developed from the concept that the anaesthetic face mask, instead of being applied to the face, could be altered and positioned over the laryngeal opening (Figure 2.1). It is inserted using a blind technique and provides a patent airway for spontaneous breathing. It is used increasingly for ventilating patients and managing difficult intubation.

Box 2.1 Methods of airway control

- Face mask and Guedel airway
- Supraglottic airway devices (SADs), e.g., laryngeal masks, i-gel airways
- Tracheal tube
- Tracheostomy



Figure 2.1 Supraglottic airway device in situ: a laryngeal mask correctly positioned before inflation, with the tip of the mask in the base of the hypopharynx

The original design of the laryngeal mask was re-usable after autoclaving. There are now many disposable options available but these are often more difficult to insert. Most SADs either require the addition of 20–30 ml of air to expand the cuff, or the i-gel is used (which has pre-formed shape); these both provide a snug fit of the mask in the oropharynx. Flexible or non-kinking versions are also used. An oesophageal port is available on some supraglottic airways such as an i-gel airway; this is designed to allow vomit to pass directly out of the tube, which in theory, minimises tracheal contamination from the vomit. An experienced anaesthetist can pass a 6.0 mm cuffed tracheal tube, elastic bougie or fiberoptic laryngoscope through a SAD. A black line is present on the tube to ensure the correct orientation of the mask. The sizes are 2 and 2½ for children, with sizes 3–5 for adults depending on their weight.

The main advantage of this technique is that the anaesthetist has both hands free to undertake other tasks. These airways permit the measurement of the oxygen, carbon dioxide and volatile anaesthetic concentration in the expired gas.

Supraglottic airway devices do not prevent pulmonary aspiration of gastric contents from occurring, are not suitable for emergency anaesthesia and incorrect positioning can occur which may cause airway obstruction. This occurs in about 10 per cent of patients and is often due to folding back of the epiglottis as it is pushed down by the airway during insertion. An obstructed airway device must be removed and repositioned. The newest generations of SADs can include a third channel for flexible scopes to aid intubation with the SAD in situ. Whilst some anaesthetists use SADs after having

administered muscle relaxants (e.g., for laparoscopy) it is wise to intubate these patients as a novice.

Tracheal Tube

A cuffed tracheal tube, once inserted into the trachea, maintains airway patency and minimises gastric aspiration into the lungs. All tracheal tubes have information written upon the tube (Figure 2.2).

The cuff is present to provide an airtight seal for ventilation and to prevent pulmonary aspiration of gastric contents. Once the tube is inserted into the trachea it is inflated with 5–10 ml of air until there is no leak of gases between the tracheal wall and the tube. Insertion of excess air into the cuff can cause it to rupture and leak. High cuff pressures can cause tracheal wall damage and mucosal ulceration.

Tracheal tubes come in many shapes and sizes. The cuff may be absent, they can be reinforced so as not to kink, they can be inserted via the oral or nasal route and some have double lumens (for deliberately deflating one lung in thoracic surgery).

A novice anaesthetist is expected to be able to provide a detailed description of the information on a tracheal tube: it is a basic tool of the trade! The tube is inserted by holding the laryngoscope in the left hand and passing the blade into the right side of the mouth. The tongue is then pushed to the left as the blade is passed down the tongue and inserted anterior

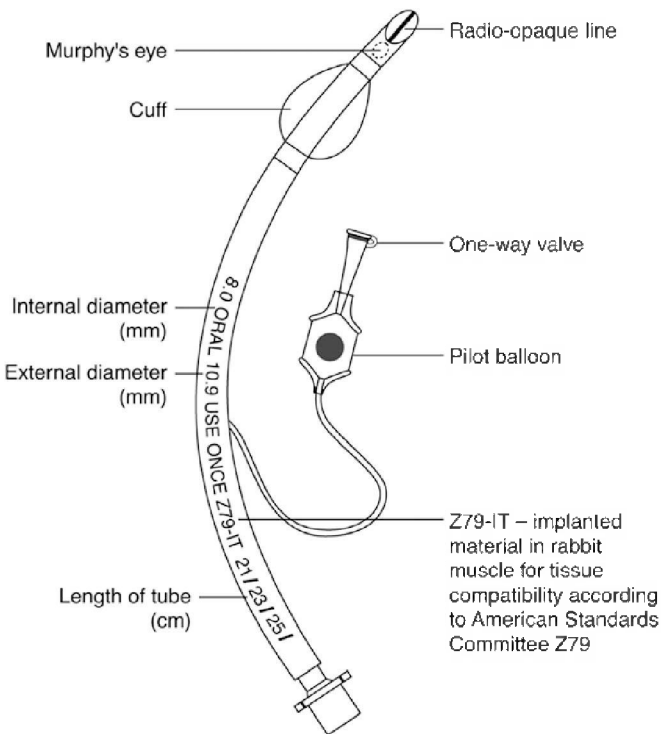


Figure 2.2 Typical tracheal tube

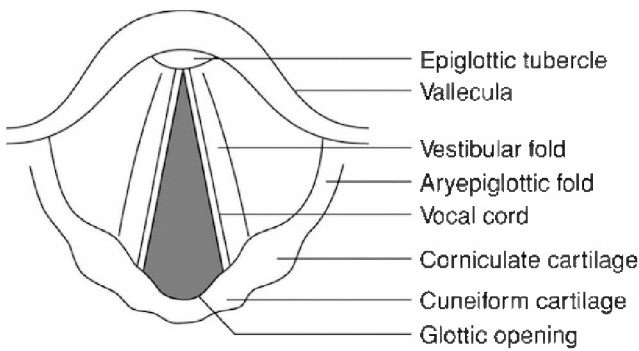


Figure 2.3 View of the larynx obtained before intubation

to the epiglottis in the vallecula. Elevation of the whole laryngoscope will facilitate a clear view of the glottic opening (Figure 2.3).

Tips to aid insertion of the tracheal tube include:

- The use of a bougie inserted through the larynx with the tube passed over it;
- The application of backwards upwards right pressure (BURP) externally over the larynx to bring it into view;
- A 'helping finger' from an assistant to pull the cheek out to allow better vision in the mouth.

The timely use of a tracheal tube introducer or bougie can make tracheal intubation easier and less traumatic. However, always take great care when using a bougie, applying cautious and gentle force and visualising the length you are introducing into the trachea, as cases of tracheal (and even bronchial!) injury have previously been reported. Occasionally, the tracheal tube impinges on the posterior rim of the larynx and will not pass smoothly over the bougie into the larynx. Rotating the tube 90° anticlockwise prevents this obstruction and facilitates intubation when using a bougie. The general principle of 'a big cannula over a small guidewire' is widely used in medicine. A size 7.0 mm tracheal tube is used for adult females and 8.0 mm for adult males. This size refers to the internal diameter of the tube. Tubes are normally cut to a length of 21–23 cm.

Tracheostomy

Tracheostomy can be undertaken with local anaesthesia and is used for airway control in the following circumstances:

- To bypass upper respiratory tract obstruction;
- For long-term ventilation of the lungs
- To facilitate suction of chest secretions;
- For prevention of pulmonary aspiration of gastric contents (e.g., in bulbar palsy).

In the event of a 'can't intubate, can't oxygenate' (CICO) emergency, every anaesthetist should know how to gain emergency front-of-neck access (eFONA) by using three simple tools: A size 10 scalpel, a bougie and a size 6.0 endotracheal tube (see Chapter 4 for failed intubation algorithm).

Percutaneous cricothyroidotomy is occasionally necessary in acute upper airway obstruction and devices which can be used for this are in every theatre complex. Learn how to use this potentially life-saving piece of equipment.

Nearly every general anaesthetic makes use of the face mask with or without a Guedel airway. These simple devices are the lynchpins of safe anaesthetic airway practice. If there is any risk of pulmonary aspiration of gastric contents, then it is necessary to secure and protect the airway with a tracheal tube. For trainee anaesthetists we suggest that all cases requiring muscle relaxation have a tracheal tube inserted. It is very easy to inadvertently ventilate the stomach with a supraglottic airway device *in situ* especially if airway pressures > 20 cm H₂O are applied, and this can cause gastric dilation and regurgitation of the stomach contents into the unprotected trachea. A supraglottic airway is suitable for uncomplicated cases with the patient breathing spontaneously.

Conclusion

Obstruction of the airway must be prevented at all times – a patent airway is a happy airway. Take care of the airway, and inquests will take care of themselves!*

* (BJA 1925).

Tracheal Intubation

Tracheal intubation is an acquired skill. Hypoxia, as a result of unrecognised oesophageal intubation, can cause death. Intubation can be performed with the patient awake (local anaesthesia) or under general anaesthesia. Intubation can be achieved using the techniques shown in Box 3.1.

Laryngoscopes

The laryngoscope is an important tool of the trade and is commonly known as the anaesthetist's best friend! It is a device used to visualise the larynx, which can be done directly or indirectly.

Direct Laryngoscopes

These carry a light source on a tongue-retracting blade, allowing direct visualisation of the larynx to aid intubation. Many variations exist, but it is always best to use a medium-length blade first when attempting intubation. The most commonly used laryngoscope, the

Box 3.1 Intubation techniques

- Above the cords
 - blind intubation
 - nasal
 - using supraglottic airway device (SAD)
 - larynx visualisation
 - oral ($\pm$ gum-elastic bougie)
 - SAD with fiberoptic laryngoscopy
 - fiberoptic laryngoscopy
 - submental intubation
- Below the cords
 - cricothyroid puncture
 - cricothyroidotomy
 - transtracheal ventilation
 - tracheostomy

MacIntosh laryngoscope, is a curved-blade device which is placed in the patient's vallecula and, by lifting of the epiglottis, allows for vision of the larynx. There must be at least two of these in every anaesthetic room. Surprisingly, the bulb often fails despite working when checked a few minutes before, so a spare laryngoscope is essential. Other types of direct laryngoscopes include the Miller blade, which has a straight blade with a curved tip and is commonly used in paediatrics, and the McCoy, which has an adjustable hinged tip.

Videolaryngoscopes (VLs)

These have revolutionised intubation over the recent decades. This is due to their improved safety profile, which has led to expert recommendations that these should be used universally as first-line tools for all intubations. Videolaryngoscopes utilise a high-resolution camera at their distal tip near the light source allowing for indirect visualisation of the larynx. Recent evidence has shown that these can improve glottic view and the first attempt at successful intubation. Like direct laryngoscopes, VLs can come in different sizes and shapes of blades. The rigid blade VLs tend to be classified as either MacIntosh style or hyperangulated. Hyperangulated blades are particularly useful for an anteriorly placed larynx. MacIntosh VL blades have the advantage that they can also be used in a conventional way to achieve direct laryngoscopy.

Some VLs, such as the AirTraqTM, can also include a channelled path to directly insert and guide an endotracheal tube through the vocal cords. Video intubating stylets have similarly gained popularity and can be rigid or flexible, such as the Bonfils and ProVu. This is because these utilise a fibrescope to navigate an endotracheal tube directly into the airway and achieve intubation using a sole device.

Using the shared screen principle the use of VLs has allowed intubation to become a shared experience and can also aid teaching and training. Lastly, the use of VLs provides the added benefit of reducing the risk of hypoxaemia and oesophageal intubation. Guidelines now suggest using VLs as the first line if difficult intubation is anticipated.

Awake Tracheal Intubation

Classically fibreoptic scopes, either flexible or rigid, have been used for intubation in the conscious and spontaneously breathing, but conventionally topicalised and occasionally sedated patient. This is a preferred technique to secure the airway if difficulty is anticipated and laryngoscopy following induction may not be a safe option, for example, in a patient in whom ventilation may be difficult due to anatomical reasons like a receding mandible or restricted mouth opening. The patient receives topicalisation of the airway prior to starting the procedure using local anaesthetic agents like co-phenylcaine spray for the nose and lidocaine for the oropharynx and vocal cords. Throughout the procedure, the patient should receive oxygen via Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) or facemask. Cautiously titrated sedative agents, if required, such as remifentanyl or midazolam, may be used to aid patient tolerance of the procedure and comfort. Intubation is then performed using a flexible scope through either the oral or nasal route. Once the glottis is visualised, the scope is guided through the vocal cords and the endotracheal tube is inserted into the trachea under direct visualisation. The correct position of the endotracheal tube in the airway should be confirmed through visualisation of the tube and the use of capnography (Box 3.2). This is an advanced airway procedure and commonly requires at least two anaesthetists and one anaesthetic assistant. The responsibility of the

Box 3.2 Clinical signs used to confirm tracheal intubation

- Direct visualisation of tracheal tube through vocal cords (and shared view if using VL)
- Unreliable signs: palpation of tube movement within the trachea, chest movements, breath sounds, reservoir bag compliance and refill, condensation of water vapour on clear tracheal tubes

first anaesthetist is the performance of the procedure, whilst the second anaesthetist oversees the pumps and administers drugs. The anaesthetic assistant will keep a close eye on the monitoring and help if any equipment issues arise. Awake tracheal intubation may also be performed using a VL and follows a similar set-up but uses a different technique. A combined technique, known as Video-assisted flexible intubation (VAFI) utilises both a VL and a flexible scope to intubate.

Laryngoscopic Views

The laryngoscopic views seen on intubation are often recorded by the anaesthetist, and have been graded by Cormack and Lehane:

- Grade I: >50% of glottis visible
- Grade II: <50% of glottis or only posterior commissure visible
- Grade III: no part of glottis but only epiglottis visible
- Grade IV: epiglottis not visible

Displacement

Tracheal tubes can be displaced after correct insertion. This is particularly likely when the patient is moved or the patient's position has changed. Flexion or extension of the head, or lateral neck movement, has been shown to cause movement of the tube of up to 5 cm within the trachea. Tracheal tubes should be fixed securely to minimise accidental extubation, and the correct positioning should be checked regularly.

Confirmation of Tracheal Intubation

Confirmation is by clinical signs and technical tests. In the operating theatre both methods are used. Unrecognised oesophageal intubation will be fatal after several minutes and a number of high-profile cases have prompted re-evaluation of this fundamental skill.

Clinical Signs

The clinical signs are listed in Box 3.2.

The best clinical method of confirming tracheal intubation is seeing the tracheal tube passing through the vocal cords. This is normally achieved easily, but is not always possible in technically difficult intubations. All anaesthetists can recount situations where they thought they had seen the tracheal tube pass through the vocal cords but subsequently found it in the oesophagus. The belief that the trachea is intubated can lead to a false sense of airway security if cyanosis occurs, and often other causes are sought for the hypoxaemia. The position of the tracheal tube must always be checked in these

circumstances. The other listed signs may be used but are unreliable in confirming correct placement of the tracheal tube.

Although an assistant applying cricoid pressure may 'feel' the tube passing down the trachea, the same sensation can also occur with an oesophageal intubation. Observation of chest wall movement is no guarantee of correct tracheal tube placement. It may be impossible to observe in some patients (because of obesity) and may occur also in cases of oesophageal intubation.

Auscultation can be misleading: gas movement in the oesophagus can be transmitted to the lungs, and so oesophageal sounds may be mistaken for lung sounds. Epigastric auscultation can be undertaken, but again breath sounds may be heard in the epigastrium, and so can cause confusion.

There is a characteristic 'feel' to the breathing-circuit reservoir bag, which is often different when the oesophagus is intubated. Reservoir bag refilling will occur in tracheal intubation, but has been described after stomach distension with oesophageal intubation. A 'rumbling' noise is often heard in oesophageal intubation, which is distinct from that heard in tracheal intubation.

Condensation of water vapour is more likely to be seen with tracheal intubation, but can be present in gas emanating from the stomach and so is considered unreliable in confirming correct tracheal tube placement. If in doubt, and if at all possible, it is worth confirming correct tracheal tube placement by viewing the tube passing through the larynx again.

Technical Tests

The commonly used tests are shown in Box 3.3.

The end-tidal CO_2 concentration can be measured using a capnograph and this has become the gold standard to confirm tracheal intubation. If pulmonary perfusion is adequate, end-tidal CO_2 concentration is about 5 per cent. No CO_2 is excreted from the stomach, so any CO_2 present must be from the lungs. Seven breaths of CO_2 must be seen to confirm tracheal intubation (see Figure 3.1). This is because alveolar CO_2 may have been ventilated into the upper gastrointestinal tract before intubation and it will take at least six breaths to excrete it from the stomach. The rises on the capnography trace should match the exhalation and inspiration phase, have a peak amplitude of $>1\text{kPa}$ (7.5 mmHg) above the baseline and should be clinically appropriate. Tube removal should be considered if a capnography trace is not restored and oesophageal intubation is suspected.

A flexible scope placed through the tracheal tube will show if tracheal placement is correct, as will ultrasound images. Although there are many tests to confirm tracheal intubation, the 'gold standard' is seven breaths of end-tidal CO_2 with visual confirmation of tracheal placement of the tube. Never attempt tracheal intubation without functioning capnography.

Box 3.3 Technical tests to confirm intubation

- End-tidal CO_2 monitoring sustained, exhaled capnography (seven breaths)
- Fibreoptic observation of the trachea
- Ultrasound (by those trained in its use)

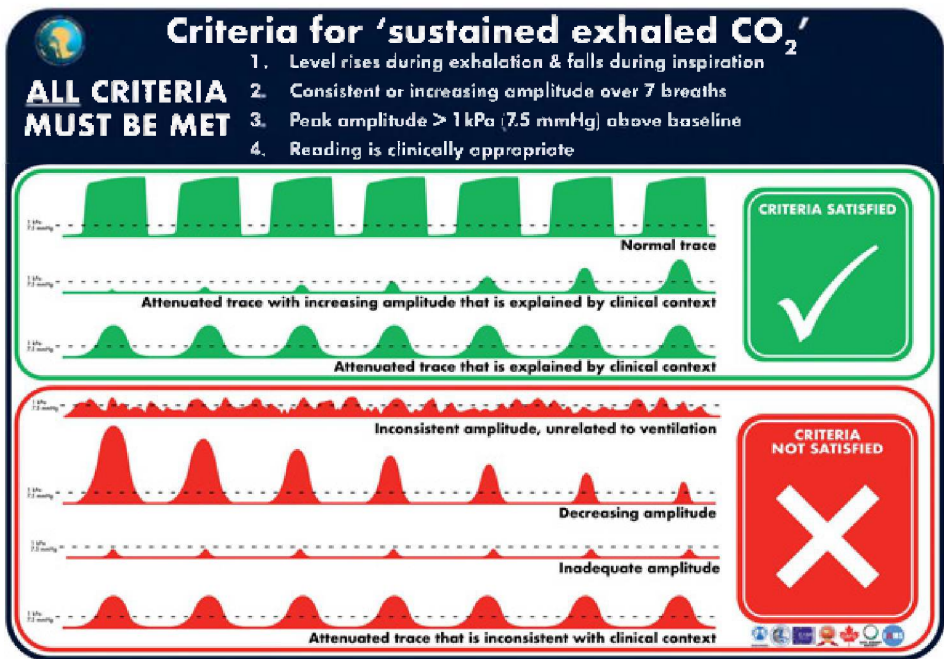


Figure 3.1 Criteria for 'sustained exhaled carbon dioxide'.

Box 3.4 Complications of tracheal intubation

- Laryngoscopy
 - trauma to mouth, teeth, pharynx and larynx
 - increased arterial pressure
 - arrhythmias
 - laryngospasm
 - bronchospasm
- Immediate
 - oesophageal placement
 - pulmonary aspiration
 - displacement of tube from trachea
 - endobronchial intubation
 - airway obstruction: tube kinked, mucous plug, tracheal cuff herniation over lower end of tube
- Long-term
 - cord ulceration with voice change
 - tracheal stenosis
 - recurrent and superior laryngeal nerve damage

Complications of Tracheal Intubation

The complications of intubation are shown in Box 3.4. The trainee needs to take special care to avoid immediate complications. Tracheal tubes can easily kink or be placed too far into the trachea and either sit on the carina or pass into the right main bronchus. High airway pressures may be seen when a patient is ventilated under these circumstances. Auscultation of the chest bilaterally may reveal a different intensity of breath sounds in endobronchial intubation. The tube is then pulled back and positioned correctly. Although almost invariably the tracheal tube passes into the right main bronchus, we have managed on rare occasions to intubate the left main bronchus.

Conclusion

The tracheal tube must be correctly sited and secured. Direct observation of tracheal placement may be helpful, but the capnography trace displaying seven breaths of end-tidal CO₂ with continuous monitoring is the gold standard and can avoid the potentially fatal consequences resulting from hypoxia. An anaesthetic maxim to remember when unsure of tracheal tube placement is:

IF IN DOUBT, TAKE IT OUT!

Patients do not die from failure to intubate but from failure to oxygenate.

The Difficult or Failed Intubation

It is essential to ask for assistance before anaesthetising patients assessed as having potentially difficult airways. Failed tracheal intubation can occur in both elective and emergency anaesthesia. It is important to prepare a management plan should intubation be impossible during the induction of general anaesthesia for every case when intubation is used. We recommend that 'failed intubation drills' should be practised when trainees are accompanied by senior colleagues. Remember it is not the failure to intubate that is the risk to patients; it is the failure of oxygenation that causes morbidity and mortality. Persistent attempts at intubation when oxygen saturations are low are very dangerous. This emergency is known as the 'can't intubate, can't oxygenate' scenario – CICO.

The Difficult Intubation Algorithm

The Difficult Airway Society (DAS) guidelines for the management of difficult unanticipated airways are core to such an emergency and every anaesthetist should be able to recall and perform the steps by heart. Calling early for help and preventing hypoxia are key!

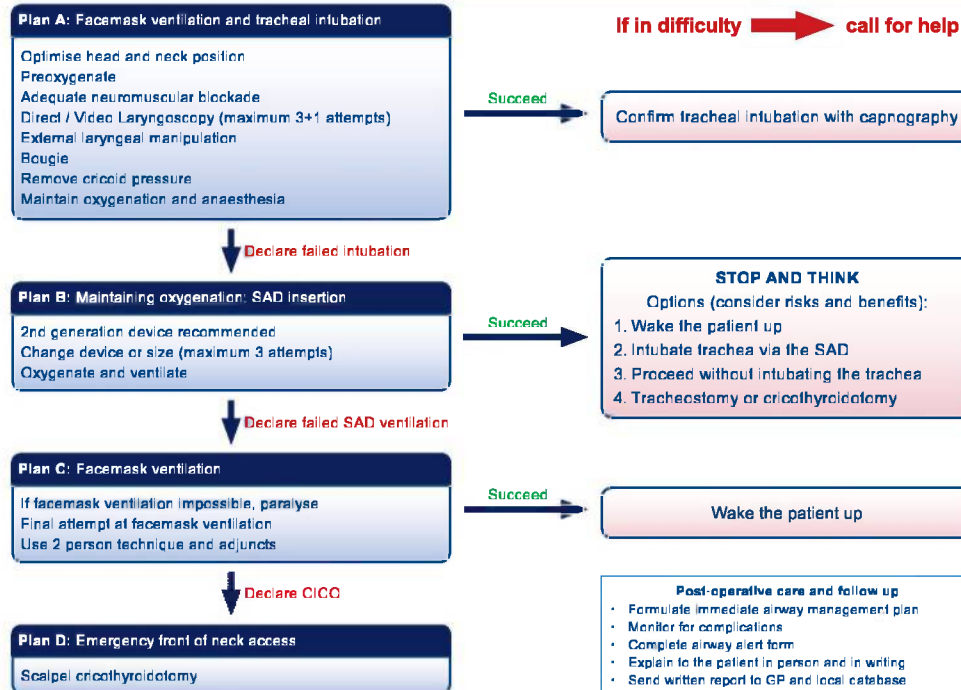
The DAS algorithm follows a sequential series of Plans A to D and should be voiced to the team prior to induction of anaesthesia (Figure 4.1). These guidelines have been developed to aid airway management in cases of anticipated difficult airways and for cases which have unexpectedly become difficult after induction. The algorithm displays a simple-to-follow flow chart and step-by-step approach. This guideline is promoted throughout the UK and has led to the use of standardised teaching and equipment. Other countries may follow their own guidelines; the USA follow the American Association of Anesthesiology (ASA) and most European countries have their own guidelines. If you are working in the UK you should be very familiar with the DAS algorithm and failing to follow it appropriately can lead to patient death and accusations of negligence.

Plan A: Facemask Ventilation and Tracheal Intubation

The first step focuses on ensuring that the first attempt at laryngoscopy and successful intubation are optimised. This includes ensuring good positioning as previously described in Chapter 2, 'Control of the Airway', as the 'sniffing the morning air' position. A ramped position is advocated especially in the overweight or obstetric population. This is best done by placing one to two pillows or the specifically designed 'Oxford pillow' under the patient's head and neck in order to achieve a horizontal line between the external meatus of the ear and sternal notch.

Peri-oxygenation is fundamental and can win you some extra time when dealing with a difficult airway! Good perioxxygenation allows an increase in oxygen levels and denitrogenation of the functional residual capacity (FRC) within the lungs in anticipation of

Management of unanticipated difficult tracheal intubation in adults



This flowchart forms part of the DAS Guidelines for unanticipated difficult intubation in adults 2015 and should be used in conjunction with the text.

Figure 4.1 DAS algorithm for unanticipated difficult tracheal intubation

apnoea following induction. If this is done efficiently it can increase apnoeic time and the time to hypoxaemia. The aim should be to achieve an end-tidal oxygen (ETO_2) of >0.8 . This may not be possible in patients who have a high oxygen consumption or low FRC either due to physiological or pathological reasons, such as severe sepsis, obesity, children and pregnant patients.

The use of neuromuscular blocking drugs (NMBD) has become a vital part of the difficult airway algorithm as it will aid good intubation conditions through full relaxation. Suxamethonium is the NMBD with the fastest onset and shortest duration of action and has previously been the most used for emergency surgery, in patients with full stomachs and in those who are at risk of regurgitation (e.g., hiatus hernia). Over the recent years, the use of rocuronium has overtaken suxamethonium for emergency anaesthesia as it has fewer side effects and can be reversed. Sugammadex, its reversal agent, can now be used to reverse the effects of rocuronium within minutes. It also works on other aminosteroid NMBDs, such as vecuronium and pancuronium. Its use has seen a steep increase in recent years due to its rapid effects. The dose of sugammadex depends on the patient's weight and the administered dose of rocuronium, varies from a dose of 2 mg/kg in a patient with a train of four count of more than 2 to 16 mg/kg for a patient with a profound block.

The now less commonly used NMBD suxamethonium is usually metabolised rapidly and is self-terminating. There is no reversal agent. Experienced anaesthetists often use NMBDs with slower onset for elective surgical patients in whom they can be confident of airway control. Muscle relaxants should not be given in cases of upper airway obstruction. If a patient is paralysed, patency of the upper airway may be lost and if oxygenation attempts prove impossible, then hypoxaemia and death will occur.

Consider why intubation has failed. A common cause in emergency anaesthesia is inexpertly applied cricoid pressure. In these circumstances, the larynx may need to be manipulated into view externally by the laryngoscopist. A bougie is helpful for railroading tracheal tubes into position when the larynx is visible, but the tube will not pass into the trachea. Do not spend time attempting these manoeuvres if the patient is becoming hypoxic. Oxygenate by ventilation. A change to a videolaryngoscope or fibreoptic scope often improves the view of the glottis. Therefore, the DAS guidelines recommend using a videolaryngoscope as the first-choice instrument in these cases. If intubation is successful, confirm tracheal placement as shown in Figure 3.1.

Only attempt laryngoscopy three times and allow a further attempt by a more senior colleague before declaring failed intubation and moving on to Plan B.

Plan B: Maintaining oxygenation – supraglottic airway device (SAD) insertion

In this step, achievement of oxygenation and ventilation remain the goal. Therefore, insertion of SAD devices is recommended commonly using second-generation devices (an example would be the i-gel®). This is because these have shown reduced risk in gastric aspiration and allow for higher oropharyngeal leak pressures.

If oxygenation via a supraglottic device has failed despite multiple attempts (again, a maximum of three) and trying different types of SADs then it should be removed, and facemask ventilation should be reattempted. At this point the intubating team is in a very stressful situation and at Plan C in the difficult airway algorithm.

If intubation has failed, further decisions have to be made (Box 4.1). The safest decision is to awaken the patient, although this may be modified by considering the elective or

Box 4.1 Subsequent decisions for consideration after failed intubation

1. Awaken patient or continue anaesthetic until senior help arrives
2. Summon experienced help – intubate under general or local anaesthesia: supraglottic airway (intubation through mask), fiberoptic intubation, blind nasal intubation
3. Proceed with surgery without intubation
4. Perform tracheostomy or cricothyroidotomy
5. Perform surgery under regional anaesthesia

emergency nature of the surgery. Patients are not usually pleased to be woken up without undergoing surgery, but at least they are alive to complain! If airway control and ventilation are easy, or the patient reverts spontaneously to breathing in an unobstructed fashion and help is nearby, the anaesthetic may be continued. A supraglottic airway can secure airway patency when other methods have failed. Sometimes it is possible to continue the anaesthetic with the patient breathing spontaneously unintubated, but tracheal intubation may be required. This can be achieved through a supraglottic airway, or via a fiberoptic laryngoscope. An airway catheter, such as the Aintree, can be inserted under direct vision with a fiberoptic laryngoscope, through the supraglottic airway followed by railroading a tracheal tube over it. Retrograde intubation can also be used occasionally. This technique involves cricothyroid membrane puncture and a guide catheter being pushed up through the larynx and out of the mouth. A tracheal tube can then be passed over the guiding catheter (the same principle as described in Chapter 3). The cricothyroid puncture devices can also be connected to a breathing circuit or transtracheal jet ventilation devices. This should only ever be attempted by experienced and trained clinicians.

A formal tracheostomy may have to be considered. Abandonment of a general anaesthetic technique and implementation of surgery under regional anaesthesia is a sensible alternative.

Plan C: Facemask ventilation

This step involves final attempts to optimise and achieve facemask ventilation using a two-handed technique and the final dilemma of either waking the patient up immediately or if all else fails Plan D – access the airway through the neck.

Facemask ventilation may be improved by performing a better jaw thrust and consideration of administering a further dose of muscle relaxant. If this has failed a CICO situation must be declared to the team and you must move on to Plan D.

Plan D: Emergency front-of-neck (eFONA)

A situation dreaded by all anaesthetists; thankfully it is rare but it may happen to you and you should know how to manage it. At this point, all attempts to ventilate and oxygenate have failed and the patient is at risk of dying imminently. Despite previous controversies as to which technique is the best, DAS recommends and teaches the scalpel cricothyroidotomy technique requiring three pieces of equipment: a size 10 scalpel, bougie and 6.0 mm endotracheal tube (ETT). This is because evidence has shown improved success rates in scalpel cricothyroidotomy over needle cricothyroidotomy.

To perform this procedure, approach the patient from the side using your non-dominant hand to perform a 'laryngeal handshake' to identify the cricothyroid membrane.

Once palpable, with your dominant hand use the scalpel to make a transverse stab incision through the cricothyroid membrane and turn the blade 90°, so that the sharp edge faces caudally. Whilst keeping the scalpel in the same place, switch hands and slide a bougie alongside the blade into the trachea. Insert the bougie up 8–10 cm followed by railroading a lubricated 6.0 mm cuffed tracheal tube. Now ventilate, inflate the cuff and confirm position. Training of this procedure has become standardised and therefore every anaesthetist should be able to perform this.

If the cricothyroid membrane is impalpable an 8–10 cm vertical incision is recommended followed by the explained steps above.

Remember to warn your future colleagues. After failed intubation, both the patient and other anaesthetists need to be informed of the difficulty in case of surgery at a later date. Therefore, the following should be noted:

- grade of intubation
- mark patient's notes with difficult airway alert
- inform patient verbally and by letter
- inform the patient's GP
- enter patient details into a local and/or national database, such as the DAS database
- complete an airway alert form or card for the patient

The patient's notes containing the clinical records should be marked stating the anaesthetic problem and including a detailed airway management plan for future use.

Conclusion

Failed intubation should be prepared for, and the priority initially should be on airway control and ventilation of the lungs with 100 per cent oxygen. It is usually safer to awaken a patient and then consider the alternatives after consultation with a more experienced colleague.

The CICO algorithm should be committed to memory very early in the training programme and practised at regular intervals. Sooner or later, it will be needed.

Remember, the objective after failed intubation is oxygenation, oxygenation, followed by OXYGENATION.

Vascular Access

Vascular access may be classified into venous (peripheral, central) and arterial. Even a novice anaesthetist rapidly gains expertise in peripheral venous cannulation. It is also important to become proficient in central venous cannulation and insertion of arterial cannulae, within the first few months of training. We have not included detailed practical descriptions of how to undertake these procedures; these skills are best learnt by careful instruction from a senior anaesthetist.

Peripheral Venous Access

Only in very rare exceptions, and none in the case of a trainee, should a general or regional anaesthetic procedure start without intravenous access. The best veins for routine use are usually on the forearm or back of the hand. The antecubital fossa may be useful in some patients especially if vasoconstricted secondary to anxiety, cold or hypovolaemia. A large-bore cannula (14 or 16 gauge) or occasionally a small cannula (20 or 22 gauge) may be used, depending on the type of surgery. Flow rates through peripherally placed cannulae are shown below (Table 5.1).

For any major surgical procedure, or one in which rapid blood loss may occur, nothing smaller than a 16-gauge cannula is essential. The major determinants of the flow rate achieved through a cannula are the radius and its length, with flow proportional to the fourth power of the internal radius, and inversely proportional to its length as shown in the equation below:

$$\text{Flow} \propto \frac{\text{radius}^4}{\text{Length}}$$

Table 5.1 Flow rates through typical peripheral venous cannulae

Gauge	Colour	Approx. Maximum Flow (mls/min)
24*	Yellow	22
22	Blue	35
20	Pink	60
18	Green	100
16	Grey	200
14	Orange	340

* Paediatrics only

So if the radius doubles, the flow increases by 2^4 , that is to say, 16 times, and if the length increases fourfold (e.g., a central line) the flow rate will decrease fourfold.

Large-bore intravenous cannulae that are inserted before induction of anaesthesia should be placed after the intradermal infiltration of lignocaine (lidocaine) using a 25-gauge needle. The ‘sting’ of the local anaesthetic is trivial compared with the pain of a large intravenous cannula pushed through the skin – we speak from bitter personal experience. Be kind to your patients. Application of EMLA or AnGel topical anaesthesia in advance is helpful for reducing the pain of venepuncture, especially in children.

Intraosseous needles provide access to the vascular system via the medullary space and can be useful in emergency situations where intravenous access has failed. These are usually inserted into the epiphyses of the tibia or humerus using a drill or manual device. It is important to familiarise yourself with these devices and techniques

Central Venous Access

Central venous cannulation is undertaken to provide venous access when the peripheral route is unavailable, to measure central venous pressure (CVP), to administer drugs and to provide parenteral nutrition. Invariably these are multilumen cannulae so that various drugs or fluids can be run simultaneously and will not mix. Usually there are three or four lumens (see Figure 5.1) often of different sizes (e.g., 14–18 G; see Table 5.2 for different flow rates).

The colour coding varies, with the distal port usually being brown. The most commonly used approach for central venous access is via cannulation of the internal jugular vein. The internal jugular vein arises as a continuation of the sigmoid sinus as it passes through the

Table 5.2 Flow rates through central venous cannulae

Gauge	Approx. Maximum Flow (ml/min)
18	25
16	50
14	80

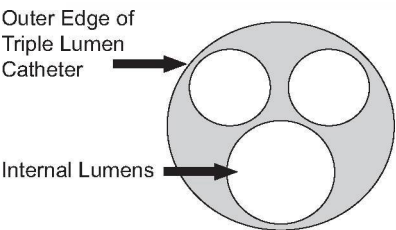


Figure 5.1 Cross section of a triple lumen of a central line

jugular foramen. It lies within the carotid sheath, lateral to the carotid artery and the vagus nerve, and runs beneath the sternal and clavicular heads of the sternomastoid muscle, where it can be 'palpated'. It finally passes under the medial border of the clavicle to join the subclavian vein.

The right side is preferred, as the veins are relatively straight on the right side of the neck and the thoracic duct is avoided. With the patient in a head-down position and the head rotated to the left, the internal jugular vein is often visible or palpable and the risk of air embolism is reduced. However, if the patient is hypovolaemic it may be impossible to ballot the vein. Using anatomical landmarks, the needle is inserted midway between the mastoid process and the sternoclavicular joint and advanced towards the right nipple. On entering the vein, a guidewire is inserted, and the cannula passed over this. This method, known as the Seldinger technique, has been shown to be safer than the traditional cannula over needle method. It can also be used for peripheral venous and arterial cannulation.

Other approaches include the use of the subclavian or femoral veins. An alternative method involves introduction of a long venous catheter, inserted via the basilic vein in the antecubital fossa, and passing into the superior vena cava. The position of this peripherally inserted central catheter (PICC) catheter should be confirmed using ultrasound or by X-ray screening, as the catheter can pass up into the internal jugular vein and even down the other arm. There are few complications with this technique, although 'damped' pressure recordings are often seen with long catheters.

Historically central venous cannulation was undertaken by palpation, but the use of ultrasound is recommended routinely to not only identify the vein but to ensure that the wire is in the vein and at the end of the procedure that the cannula is appropriately positioned. Trainees should become proficient in the use of ultrasound early in their careers. The internal jugular vein is easy to visualise as it is compressible and lateral to the pulsating carotid artery (see Figure 9.3). Strict asepsis should be used when inserting central venous cannulae. This means a surgical mask, gown and gloves and the use of a skin-cleansing agent such as chlorhexidine 2%. Although internal jugular vein cannulation is relatively safe in skilful hands, problems can occur (Box 5.1).

Box 5.1 Complications of internal jugular vein catheterisation

- Immediate
 - venous haematoma
 - carotid artery puncture haematoma
 - pneumothorax
 - haemothorax
 - cardiac tamponade
 - nerve trauma (brachial plexus, vagus, phrenic)
 - air embolism
- Delayed
 - infection

Box 5.2 Variants in central venous pressure

- Low pressure
 - hypovolaemia
 - respiratory phase variation
- High pressure
 - hypervolaemia
 - right ventricular dysfunction
 - increased right ventricular afterload
 - pulmonary hypertension
 - parenchymal pulmonary disease
 - pneumothorax
 - haemothorax
 - left heart failure
 - atrial arrhythmias
 - tricuspid valve disease

The type of device and number of lumens depends upon the indication for insertion and the intended duration of use. The final position of the catheter should be checked by X-ray to ensure appropriate placement and exclude a pneumothorax.

Central venous pressure is measured from the midaxillary line via a pressure transducer. The height of the transducer is very important – if, for example, it has fallen on the floor the CVP will be reading spuriously very high! There is no normal CVP. It is the response to an intravenous fluid load that determines whether the patient is hypovolaemic or not. The causes of variants in central venous pressure are shown in Box 5.2.

Haematomas are the most common complication and can be disastrous if the patient is anticoagulated. A bilateral haematoma can even threaten the airway. Pneumothorax is less common with the advent of ultrasound.

Arterial Cannulation

An arterial line can be used in theatres and in ICU but never outside of these environments. This is because in the case of unrecognised disconnection or the three-way tap left open, blood loss will continue, potentially only stopping when the patient has exsanguinated. Lines are inserted for beat-by-beat measurement of blood pressure – very useful for long cases or where major haemorrhage is expected. They also allow arterial blood gas sampling and are useful when blood pressure cuffs are unreliable (e.g., a large patient with arms by their side). Arterial cannulation is commonly performed via the radial artery (rarely brachial, femoral or dorsalis pedis) with a 20- or 22-gauge cannula. Historically an Allen's test was done to assess the relative contributions of the radial and ulnar arteries to blood flow of the hand. This is done by occluding both the radial and ulnar arteries and then watching for 'palmar flushing' when the ulnar artery is released. If flushing occurs, then it implies that, in the event of radial artery trauma or occlusion, the ulnar artery will supply the hand. In practice, we never bother with the Allen's test as its value is not proven. The use of

ultrasound will allow visualisation of the artery and surrounding structures and should be considered early if arterial cannulation proves difficult.

Complications of arterial cannulation include thrombosis, infection, fistula, aneurysm and distal ischaemia. These are rare but, in the event of clinical ischaemia, the cannula should be removed and expert help sought urgently. Colour-coding of arterial cannulae and their dedicated infusion tubing with red tags and red three-way taps should be undertaken if possible. This reduces the risk of inadvertent injection of drugs into arteries. Care should also be taken to avoid entry of air, which if under pressure could travel retrogradely into the cerebral circulation.

Conclusion

Intravenous access is mandatory before starting any form of anaesthesia, local or general. If there is any possibility of rapid blood loss, insert a large-bore intravenous cannula. Lack of vascular access is a major contributor to anaesthetic disasters. Ultrasound is mandatory for central venous cannulation and can be a useful adjunct when confronted with difficult peripheral venous and arterial cannulation.

Pharmacology: A Brief Introduction

Many of the drugs you will encounter within theatres and intensive care will naturally be unfamiliar to you, as many of these agents are used almost exclusively within this environment. In addition, it is commonplace for drugs to be drawn up in syringes in advance of their intended use and therefore all drugs in the theatre environment are identified with colour coded adhesive labels. It is therefore imperative that any drug for administration has been personally drawn up and checked by the person giving the drug – do not rely on others. The inadvertent and unrecognised intravenous administration of neuromuscular blocking drugs to a conscious patient, or adrenaline or local anaesthetics, can be at best unpleasant and at worse fatal. Remember to:

1. Labelling and packaging of drugs can be similar and mistakes occur from new formulations looking superficially like another drug. Never assume a drug is what it is without checking!
2. Some drugs are manufactured in different concentrations (e.g., midazolam and propofol) so ensure that you have the concentrations you think.
3. Great care is needed if drugs are diluted (e.g., for paediatrics) and many use undiluted drugs in a 1 ml syringe to minimise this risk.
4. Emergency drugs should always be to hand. These include drugs to treat bradycardia, hypotension and to facilitate tracheal intubation.

Allergy to Anaesthetic Drugs

Allergic reactions to anaesthetic drugs can be minor (e.g., some arm or facial flushing) to anaphylaxis. Recognising and treating the more severe allergies, although relatively rare, can be lifesaving. Antibiotics and muscle relaxants make up around 80% of anaphylactic reactions associated with anaesthesia and surgery (with chlorhexidine and patent blue dye less commonly implicated). This topic is dealt with in detail in Chapter 14. A few of the major drugs classes are discussed below.

Intravenous Induction Agents

These are used to induce anaesthesia and cause unconsciousness or lack of awareness. They are used prior to any airway manoeuvres (such as tracheal intubation) and administration of muscle relaxants and of course surgery itself. They can also be used to maintain anaesthesia (see the last section of this chapter on TIVA).

Propofol (2,6-diisopropylphenol)

This agent is used almost exclusively for both elective and emergency surgery. It is supplied as a white emulsion in soyabean oil and egg phosphatide, but it is safe to use in patients with an allergy to egg. Its benefits are that it is not cumulative due to rapid metabolism, so patients wake up clear-headed and have a low incidence of postoperative nausea and vomiting (PONV). Its principle adverse effect is hypotension (due mainly to vasodilation) and drugs should always be available to counteract this (see the section on cardiovascular drugs). It can also cause pain on injection – using a larger vein and pre-dosing with lidocaine reduces this. Propofol's metabolism and clearance profile lends itself to infusion to maintain anaesthesia, and even after an infusion of several hours, it still wears off rapidly. It has no active metabolites. It can cause pain on injection, especially in small veins. It works by enhancing the inhibitory effects of gamma-aminobutyric acid (GABA).

In combination with remifentanyl, propofol is very popularly used as total intravenous anaesthesia (TIVA), without the need to use volatile anaesthetics. Generally, these require infusion pumps to deliver, which have computer algorithms to deliver target controlled infusion (TCI), which maintain plasma levels of both the propofol and remifentanyl once patient demographics have been entered. There is some enthusiasm for preferring TIVA to volatile based anaesthetics for patients undergoing major cancer surgery with some evidence that long-term outcomes may be improved with this technique.

Other Agents

Thiopentone is a barbiturate that for many years prior to the introduction of propofol was the main induction agent. It causes less hypotension but is cumulative after repeat doses. It also has anticonvulsant properties.

Midazolam is occasionally co-administered to patients at induction and will reduce the required dose of propofol. Whilst causing amnesia it has active metabolites leaving patients drowsy for some time afterwards. Its principal use is by non-anaesthetists in endoscopy and radiology and so on, where small doses can be given usually without the need for airway support or intervention. It is also used sometimes as an anxiolytic for premedication.

Ketamine is sometimes used at the start of an anaesthetic. It will cause unconsciousness with some preservation of airway reflexes in large doses and has analgesic actions too. Its major benefits are the lack of cardiovascular upset and it is sometimes used for patients *in extremis*. It can be used for out of hospital procedures (e.g., patients trapped in a car) and can also be administered intramuscularly. It can cause unpleasant dysphoric reactions on emergence. Lower doses are used to provide analgesia and it is sometimes used both parenterally and orally postoperatively for patients with complex pain requirements.

Opioids

These are controlled drugs and whilst longer acting agents such as morphine, diamorphine and pethidine are used outside and inside of theatres, you will also see the use of rapid onset and relatively short duration of action opioids that are co-administered with propofol to facilitate a smooth induction, supraglottic airway or tracheal tube insertion and perioperative analgesia. The rapid onset and offset of these drugs is useful, but beware that they also can rapidly cause apnoea, especially alfentanil and infusions of remifentanyl.

Table 6.1 Side effects of opioids

Respiratory depression	Dysphoria
Cough suppression	Bradycardia
Constipation/ileus	Opioid induced hyperalgesia
Nausea and vomiting	Tolerance
Histamine release (itching)	Addiction

Fentanyl has a relatively short duration of action and will provide analgesia for surgery and into the early postoperative period. It is also used for spinal and epidural anaesthesia where it acts on spinal opioid receptors and is usually co-administered with local anaesthetics.

Alfentanil has a very rapid onset and offset, rapidly causing apnoea. Its rapid onset is useful for obtunding the responses of tracheal intubation or SAD insertion.

Remifentanil is a very potent drug and is useful as it undergoes organ independent elimination by plasma esterases, so is not cumulative even in patients with little or no liver and renal function. This lack of cumulation makes it ideal to be used with propofol as the TIVA technique.

Morphine is the gold standard opioid to which others are compared. It has a relatively slow onset and offset and the latter makes it useful to supply opioid analgesia into the postoperative period. It can be administered orally (oromorph – not a controlled drug), intravenously (including patient-controlled analgesia – PCA), intramuscularly and subcutaneously (this route is more common for medical or end of life patient care). It may also be used for spinal anaesthesia but here its longer duration of action can put patients at risk for delayed respiratory depression (up to twenty-four hours later).

Diamorphine is used principally for epidural and spinal anaesthesia where its duration is less than morphine, usually several hours. Other drugs include pethidine (used almost exclusively in obstetrics) and oxycodone.

There are many side effects of opioids which you need to become familiar with (see Table 6.1). Whilst good analgesics, their side effects have prompted the minimisation (or even avoidance) of opioid use and the postoperative analgesia is generally administered as ‘multimodal opioid sparing’ to reflect these concerns. A particular problem is encountered with patients who are receiving high doses of opioids preoperatively, when attempting to control their postoperative pain.

Neuromuscular Blocking Drugs

Neuromuscular blocking drugs (NMBDs), also referred to as muscle relaxants, will cause rapid paralysis and clearly need to be given when the patient is unconscious (as it is highly unpleasant to administer to a conscious patient) and where airway maintenance, skilled help and so on are available. Accidental administration of even small doses of the agent (including in the ‘dead space’ of a cannula postoperatively) can be catastrophic particularly if unrecognised. They have revolutionised the delivery of anaesthesia, providing smooth intubation, good operating conditions especially for abdominal surgery and preventing coughing (which can be catastrophic during some surgeries such as neurosurgery and ophthalmic surgery).

Classically these drugs are subdivided into depolarising and non-depolarising agents. Suxamethonium is the only depolarising NMBD in use and was used for many years as it has a rapid onset together with rapid offset (due to metabolism by plasma cholinesterase) – ideal for tracheal intubation and rapid sequence induction. It has numerous side effects including severe allergy, muscle pains and more rarely and seriously is a trigger for malignant hyperthermia, prolonged metabolism in patients with plasma cholinesterase abnormalities and hyperkalaemia in patients several months following significant burns. Its use for rapid sequence induction (RSI) has diminished as the rocuronium/sugammadex combination has become more commonly used.

There are several non-depolarising muscle relaxants. Generally, these have a much slower onset (which can be hastened by giving a larger dose) and a longer duration of 20 minutes or more. They are sometimes referred to as competitive muscle relaxants, indicating that they compete with acetylcholine and their receptors, at the neuromuscular junction, thus interrupting normal neuromuscular transmission.

Rocuronium has become a very popular agent. It has few side effects. A related drug is vecuronium, which has a similar profile. Atracurium is a different class of drug and can cause marked histamine release. However it is non-cumulative, being metabolised into non-active metabolites by plasma esterases, and is therefore useful for patients with little or no hepatic or renal function where its metabolism is unchanged. An isomer of atracurium – cisatracurium – has the same metabolism characteristics but is longer acting.

The majority of drugs used during an anaesthetic are not reversed at the end of surgery, they merely wear off. An exception is the non-depolarising muscle relaxants, which if not reversed can lead to partial paralysis, which is unpleasant and dangerous for patients (increased risk of inadequate ventilation and airway protection). For many years the use of the anticholinesterase neostigmine was used, in conjunction with an antimuscarinic drug (atropine or glycopyrrolate) to prevent excessive parasympathetic activity such as bradycardia and salivation. These drugs will not work at very deep levels of block.

More recently the aminosteroid non-depolarising muscle relaxants (rocuronium and vecuronium) can be very rapidly and efficiently reversed by a cyclodextrin called sugammadex, which encapsulates these drugs and terminates their action, even at a very deep level of neuromuscular block (although a higher dose is required). It has no action on atracurium or cisatracurium.

Volatile Agents

These agents can be used for both induction and maintenance of anaesthesia. Gaseous induction of anaesthesia is particularly useful in children and those with severe needle phobia. Whilst historically these agents have had a major role many are obsolete (ether, chloroform, halothane) and the principal agent in use is sevoflurane. Another drug with very rapid offset is desflurane but this has now been decommissioned as it has a very harmful environmental profile.

Sevoflurane is a most useful agent. It is relatively insoluble in blood and in the alveoli (and soon after in the brain) it rapidly builds up a significant partial pressure and thus exerts its effect. Volatile agents are usually described in terms of their MAC (minimum alveolar concentration) value with a potent agent having a low value (i.e., a low concentration required to maintain anaesthesia). Anaesthetic machines measure both inspiratory and expiratory concentrations which is very useful as end-tidal concentrations reflect brain concentration and thus confirm depth of anaesthesia.

Minimum alveolar concentration values are defined as the minimum alveolar concentration required to prevent purposeful movement in response to a surgical stimulus in 50% of patients. Whilst this may not sound like a very useful benchmark, in fact administering a MAC of around 1 (in the case of sevoflurane this equates to 2.0% for adults aged 40) is often used to ensure adequate anaesthesia. Minimum alveolar concentration values vary with age with lower values in neonates and again lower in those aged 40 and over (after the age of 40 MAC requirements decrease by about 6% per decade). Minimum alveolar concentration values are additive so if nitrous oxide is used (see below) then lower concentrations of sevoflurane are required to obtain a satisfactory MAC value.

Cardiovascular Drugs

Anaesthesia and surgery inevitably cause a degree of cardiovascular upset. In particular drugs need to be on hand to treat hypotension (often related to vasodilatation), such as vasoconstrictors (metaraminol or phenylephrine) or sympathomimetics (ephedrine). Some drugs and/or procedures may cause marked bradycardia and antimuscarinic agents such as atropine and/or glycopyrrolate need to be drawn up too.

Nitrous Oxide

Nitrous oxide has been used since the mid-nineteenth century initially for dental anaesthesia. It has a high MAC value of 105, so even 80% nitrous oxide in oxygen will not permit surgery to take place without other agents being used. Its principal use is to provide rapid onset of analgesia and it is used widely in obstetrics and A&E departments as a mixture of 50% nitrous oxide and 50% oxygen (Entonox). Known as laughing gas, its euphoriant effect has made it a substance of abuse for over 200 years and this abuse potential has resulted in it recently being classified as a Class C drug under the Misuse of Drugs Act. It has a confirmed place in paediatrics to provide rapid inhalational induction of anaesthesia with sevoflurane. It has many disadvantages such as distension of air-containing cavities (bowel, middle ear and retinal detachment surgeries), postoperative nausea and vomiting and a harmful environmental profile and is now less commonly used; oxygen and air mixtures are preferred as carrier gasses for volatile anaesthetics.

Other Drugs Commonly Administered by Anaesthetists

Antibiotics

These are often given on induction of anaesthesia to reduce the risk of bacteraemia from surgery (e.g., urology and many gastrointestinal surgeries). This is a key area as postoperative sepsis (e.g., urosepsis, surgical site infection) can sometimes be traced to omission of these drugs. In addition, patients having various implants (e.g., hernia mesh, vascular implants, cardiac valves, joint replacements etc.) require antibiotics. Beware of allergy (such as penicillins and teicoplanin) and side effects (such as gentamicin and its nephrotoxicity).

Drugs Affecting Coagulation

You may be asked to give drugs that promote coagulation such as fibrinolytics (e.g., tranexamic acid) or drugs to prevent coagulation (e.g., heparin during major cardiac and vascular cases).

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Drugs for Imaging

Sometimes the surgeons require administration of various agents which will aid in imaging tissues, lymph nodes and vascular anatomy such as indocyanine green (ICG) and patent blue.

Total Intravenous Anaesthesia or Volatile?

Anaesthetists will need to gain experience in delivering both of the above techniques and it is therefore natural to ask 'which is better?' The answer is unknown but there is increasing enthusiasm for TIVA particularly for longer cases where rapid clear-headed recovery is commonplace. There is some evidence too that TIVA may contribute to improved long-term cancer survival. In addition the environmental impact of TIVA may be less than volatiles but volatile capture in scavenging may change this.

Intravenous Fluids

Intravenous fluids can seem a mystifying area of clinical practice with a bewildering array of fluid types and regimes. Fluids and electrolytes are administered to replace and/or maintain the body's requirements, but in addition, should be seen as a major area in the maintenance and manipulation of cardiac output and hence oxygen delivery (see Chapter 10).

Often patients arrive in theatres somewhat dehydrated, as they are starved preoperatively to ensure an empty stomach. Although in theory, patients only need to be fasted for six hours for food and one hour for water prior to surgery, in practice some patients are starved for much longer (e.g., overnight for over 12 hours) due to incorrect advice, not reading or understanding the advice or because of list order changes. In addition, patients may be further dehydrated if they are vomiting or have had bowel preparation. Some of these effects have been mitigated more recently by the use of carbohydrate loading, which is usually 800 mls and 400 mls of oral 'preload' fluid the night before, and the morning of, major elective surgery.

In all but the most minor surgery, most patients receive some intraoperative IV fluids. A major choice is between crystalloid and colloid solutions and for many years the crystalloid–colloid debate has raged. Crystalloids are salt solutions that will diffuse from the vascular compartment into the interstitial space with only about 25 per cent retained in the intravascular compartment. Colloids are composed of larger molecules than crystalloids and thus are retained in the intravascular compartment much longer than crystalloids.

Crystalloids include 0.9% normal saline (which is far from normal with unphysiologically high sodium and chloride concentrations), which can lead to hyperchloraemic acidosis and renal impairment and is thus rarely used. Balanced crystalloid solutions, which are almost universally used, are solutions containing electrolytes and pH close to that of plasma as seen in Table 7.1. Typical examples are Plasmalyte and Hartmann's solutions. There is no logical place for 5 per cent glucose, which can cause unwelcome hyperglycaemia with its risks (e.g., increased infections), and when oxidised, will effectively become water, with no significant expansion of the intravascular compartment. Colloids include hydroxyethyl starches (HES), gelatin and human albumin solution (HAS). There is some evidence suggesting an association with kidney injury with HES, and all can rarely cause serious allergies.

In general, most anaesthetists will use balanced crystalloids as the first line in the operating theatre, although both crystalloids and colloids (HAS) are administered on the intensive care unit.

The lactate in Hartmann's solution is either oxidised in the liver, or undergoes gluconeogenesis.

Table 7.1 Electrolytic composition of intravenous crystalloid solutions (mmol/l)

Solution	Na	K	Ca /Mg	Cl	Other anions
0.9% Sodium chloride	154	–	–	154	–
Hartmann's solution	131	5	2 (Ca)	111	29 lactate
5% Glucose	–	–	–	–	–
Plasma-Lyte 148	140	5	1.5 (Mg)	98	27 acetate 23 gluconate

How Much Fluid?

In practice, most anaesthetists start with 1–2 l of crystalloid. This will suffice for most procedures where patients will be eating and drinking later in the day. For major or prolonged surgery large volumes may be required as may blood products. Both hyper and hypovolaemia are undesirable, as both will ultimately impair tissue oxygenation, and are associated with significant morbidity. The ultimate aim is to have adult patients around zero balance or slightly positive (approximately 1 l). The rate of administration varies, often according to the habits of individual anaesthetists, and can be from as little as 1 ml/kg/h up to 10 ml/kg/h. If in doubt, 3 ml/kg/h is a good starting rate of infusion in a patient who is not dehydrated. A markedly dehydrated and/or septic patient may need to be resuscitated with a very large bolus, for example, up to 20–30 mls/kg.

Fluids are given intraoperatively to:

- replace existing deficits (can be high, e.g., emergencies, bowel obstruction, prolonged starvation)
- maintain fluid balance (normal maintenance requirements for adult patients are about 50–100 mmol/day of sodium, 40–80 mmol/day of potassium and 2–3 l/day of water)
- replace surgical loss (both blood/fluid loss and insensible losses from evaporation)

Although in the past, response to a fluid challenge (e.g., 250 mls of crystalloid) was assessed by increased urine output, arterial blood pressure and reduced heart rate to guide fluid therapy, for major cases central venous pressure increases and more latterly flow measurements (such as stroke volume and cardiac output optimization) are employed.

Controversies

It may surprise the new trainee that there is not clear guidance on the choice of intravenous fluids perioperatively. At present the current recommendations are to use a balanced crystalloid solution during surgery (not 0.9% sodium chloride) and immediately perioperatively, with early drinking encouraged where feasible so that IV fluids can be tapered off. Prolonged IV fluids or complex patients (e.g., large GI losses, fistulae etc.) will require careful crystalloid replacement often with potassium and magnesium as well. Doubt has also been cast on the value of urine output as an indication of the adequacy of fluid replacement as postoperative oliguria is a normal physiological response and chasing the classical 0.5 mls/kg/hr with excessive fluid is no longer recommended. However, a good urine output is a reassuring sign.

Conclusion

Start with 1–2 l of balanced crystalloid solution. Repeat this, if necessary, for prolonged surgery. If there is marked blood loss, consider red cell replacement (see Chapter 13). For major surgeries and/or unwell patients consider early invasive monitoring arterial and central lines and flow directed therapy to optimise stroke volume.

The principles of fluid management need to be seen within the context of overall haemodynamic therapy, and once stroke volume optimisation has been achieved, and particularly if the mean arterial pressure is low then vasoactive drugs should be administered, not further fluids (see the algorithm in Chapter 24 on emergency laparotomy). Finally, ideally patients should be weighed postoperatively to detect early increases in weight from over-enthusiastic fluid administration.

Anaesthetic Equipment: The Machine, Breathing Systems and Ventilators

The Anaesthetic Machine

The anaesthetic machine is designed to enable oxygenation, safe delivery of both gases and volatile anaesthetic agents and appropriate ventilation to the patient. The machine has seven basic components (Box 8.1). Today, most modern machines are complex pieces of equipment dependent on electronic hardware and software. Many incorporate an array of electronic systems for monitoring both the patient and the gas delivery to and from the patient. In addition, integral breathing systems and ventilators may be included to produce the modern 'Anaesthetic Workstation'. However, in any department there may be a mixture of old and new machines. It is vital to ensure you are familiar with the anaesthetic machine in use before embarking on an anaesthetic. National guidelines exist which emphasise the importance of both understanding and checking any equipment to be used. These checks should be followed before every session.

Gases from different sources are delivered at different pressures. In addition, different nomenclature for pressure readings in use in machines can cause confusion. The derived SI (Système Internationale) unit of pressure is the pascal (Pa), and pressure in the anaesthetic machine is measured in kilopascals (kPa). The comparative factors for other units of pressure are shown in Box 8.2

Gas Supply

Pipelines

The primary source of gas is usually via pipelines drawn from a central supply and fed into a labelled and colour-coded distribution network terminating in self-closing Schrader

Box 8.1 Anaesthetic machine components

- Gas supply – via pipelines from a wall supply or cylinders attached to the machine
- Pressure gauges and regulators – these monitor and protect both patient and machine from excessive pressures
- Flowmeters and rotameters – allow gas flow to the patient to be titrated accurately
- Vaporisers – allow delivery and accurate control of concentration of volatile anaesthetic agent
- High flow oxygen flush – bypasses flowmeters and vaporisers to provide pure oxygen at 30–75 l/min
- Common gas outlet
- Scavenging systems – to dispose of spilled agents

Box 8.2 One atmosphere of pressure (various units)

- 760 mmHg
- 1034 cm H₂O
- 15 lb/in²
- 101 kPa
- 1 bar

sockets at the wall. Flexible pipelines, colour coded for each gas (oxygen, white; nitrous oxide, blue; medical air, black/white) (Box 8.3), deliver gases from the wall outlet to the anaesthetic machine. Each pipeline is connected to its respective wall outlet by means of a non-interchangeable Schrader valve or probe. These have a protruding gas specific collar that only fits the corresponding recess for that gas. It should not be possible to connect these incorrectly. The connection at the anaesthetic machine uses a non-interchangeable screw thread system (NIST) to ensure a hose connection specific to each gas. There is also a one-way valve to ensure unidirectional flow.

Oxygen normally comes from a liquid cryogenic source, and nitrous oxide from central banks of cylinders. Piped medical air may be from a cylinder bank or compressor. The pressure of pipeline-supplied gases is 400 kPa. Medical suction is connected to a vacuum source via a yellow pipeline. This is normally located centrally within the hospital. The yellow piping is non-interchangeable and the suction system is connected to a high-volume displacement pump that is linked by a series of anti-contamination traps to a central reservoir. The acceptable flow rate for suction devices is 35 l/min of air at a maximum of 80 kPa negative pressure.

Box 8.3 Pipelines

- | | |
|---------------------|--------|
| • O ₂ : | white |
| • N ₂ O: | blue |
| • Suction pipeline: | yellow |

Cylinders

Cylinders are made of molybdenum steel. They come in different sizes with different storage capacities and are colour-coded:

- | | |
|---------------------|---------------------------------|
| • N ₂ O: | blue body, blue shoulder |
| • O ₂ : | black body, white shoulder |
| • Air: | grey body, white/black shoulder |
| • CO ₂ : | grey body, grey shoulder |
| • Entonox: | blue body, blue/white shoulder |

Cylinders are attached to the anaesthetic machine via a yoke which supports the cylinder and ensures unidirectional flow. This also contains a Bodok seal, a non-combustible neoprene washer with a copper ring, to ensure a gas-tight seal to stop leaks occurring between the cylinder and the machine. To prevent incorrect placement of the cylinder onto the machine, there is a pin-index system. On each cylinder is an arrangement of three holes specific to that gas, and there is a corresponding pin on the machine.

Oxygen and air cylinders contain gas. The pressure in a full oxygen cylinder is 137×100 kPa and the pressure decreases linearly as the cylinder empties. Carbon dioxide and nitrous oxide are stored as liquids in equilibrium with their saturated vapour. A full nitrous oxide cylinder contains liquid up to a maximum of 80 per cent of its volume and a pressure of 52×100 kPa. The pressure in the cylinder remains the same as it empties, until all the liquid becomes gaseous (when the cylinder is about a quarter full) and then the pressure drops rapidly.

Pressure Gauges

Bourdon-type pressure gauges indicate the cylinder and pipeline pressures. Each gauge is calibrated for an individual gas or vapour. When cylinders are used, the pressure gauge can help determine when the cylinder is nearly empty.

Pressure Regulators

Beneath the machine are pressure-reducing valves which regulate the pressure entering the machine (Figure 8.1). These reduce cylinder pressure to a suitable supply pressure and compensate for pressure fluctuations as the cylinder content decreases.

Gas at high pressure enters and passes through a small port to a low-pressure chamber. As the pressure here rises, the diaphragm is pushed up against the spring and the valve is closed. If the outlet valve is opened, the pressure drops and the spring will push the diaphragm down, and the whole process starts again. This ensures the pressure of all gases entering the machine is 4×100 kPa.

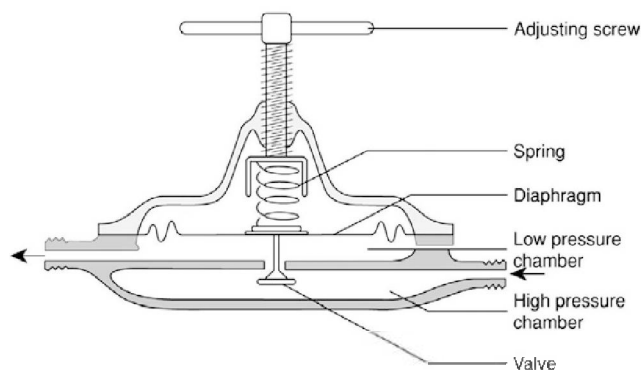


Figure 8.1 A pressure-reducing valve

Flowmeters and Rotameters

The flowmeter allows gas flow to the patient to be titrated accurately. It consists of:

- A flow control (needle) valve
- A tapered transparent tube
- A rotating bobbin or ball

At the common gas outlet of the machine the pressure has fallen to almost atmospheric. In older mechanical machines the main pressure drop occurs across the needle valve at the base of the rotameters. However, in modern machines electronic compensation microprocessors regulate pressure and flow within the machine. These have the ability to allow low flow anaesthesia <1 l/min.

The knobs are colour-coded with the oxygen knob bigger and of a wider, more grooved nature than the others. This enables it to be identified in darkness. In the United Kingdom it is conventional for the oxygen valve to be mounted on the left side of the machine.

Traditional flowmeters have been of the rotameter type. These are calibrated specifically for each gas and are non-interchangeable. Cracks in the rotameter tubing may lead to hypoxic mixtures being produced and so an oxygen gas analyser is positioned at the common gas outlet on the machine. The scale on the rotameter is often non-linear, as the rotameters themselves are tapered. Most machines now give a digital readout or a virtual representation of a flowmeter rather than using rotameters.

Vaporisers

Vaporisers are connected to the 'back bar' of the anaesthetic machine. An O-ring washer system must be present at this site to stop leaks. Vaporisers are specific for each agent. Their purpose is to convert a volatile liquid anaesthetic into a continuous-flow anaesthetic vapour mixed with gases, under controlled conditions. Thermal energy is used in converting a liquid to vapour, and a temperature drop occurs within the liquid. Variable rates of vaporisation will therefore occur without compensation and so temperature compensation (known as Tec-type) vaporisers are in common use. Compensation may be achieved by attaching the vaporiser to a metal jacket to minimise temperature fall and use of a bimetallic strip within the machine. A vaporiser with an integrated heater is available for agents with a boiling point close to room temperature such as desflurane.

A vaporiser should be constructed of materials of high specific heat and high thermal conductivity. Within the vaporiser are a series of copper helical wicks which provide a large surface area, ensuring that a saturated vapour pressure exists within the vaporiser at all times.

Vaporisers should be filled at the end of the operating list to decrease pollution. A non-interchangeable filling device ensures that each vaporiser is filled with the correct agent.

High Flow Oxygen Flush

This button connects directly to the high-pressure oxygen source to deliver oxygen to the common gas outlet, at a rate of over 35 l/min, bypassing the vaporisers and flowmeters.

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In addition to this, two other safety features on the machine must be noted:

- Hypoxic or oxygen failure alarm. This device causes the nitrous oxide to be cut or dumped if the oxygen supply is <21 per cent. This can occur if the oxygen rotameter is accidentally bumped or turned down, or if it fails electronically. An audible alarm is heard when this is activated.
- Pressure relief valve. On the 'back bar' between the common gas outlet and the vaporisers, there is a pressure release valve which protects the machine against excessive pressure caused by obstruction to gas flow beyond the common gas outlet. This does not protect the patient but is designed to protect the machine. It is activated by back pressure in excess of a third of an atmosphere (35 kPa). Newer machines do not have relief valves and rely on microprocessors to regulate the back pressure in the machine.

Common Gas Outlet

The gases leave the anaesthetic machine via the common gas outlet at which stage they are about atmospheric pressure. The oxygen analyser is connected here.

Scavenging Systems

Anaesthetic gas scavenging systems are designed to safely remove anaesthetic waste gases and consist of three main components (Box 8.4). Chronic and short-term exposure to inhalational anaesthetic agents is considered to be detrimental to the health of theatre workers, although there is no conclusive evidence of impaired concentration, physical health or fetal well-being in pregnant women.

Nitrous oxide and fluorinated agents such as sevoflurane, desflurane and isoflurane are greenhouse gases. As these undergo minimal metabolism in the body and are primarily eliminated unchanged via exhalation, there are increasing concerns on the impact of these agents on the environment. Suggested additional measures to both reduce occupational exposure and the environmental impact include the avoidance of nitrous oxide and desflurane, the use of low flow anaesthesia or the use of total intravenous anaesthesia.

Box 8.4 Scavenging system components

- *Collecting system.* This is a shroud enclosing the Adjustable Pressure-Limiting Valves (APL) valve of the breathing system. The connection is of 30 mm diameter to prevent accidental connection to the breathing system circuit (22 mm).
- *Receiving system.* This has a reservoir to ensure adequate removal of gases. A rubber bag, or a rigid bottle, is often used, and this ensures that removal of gases occurs even if the volume cleared is less than the peak expiratory flow rate.
- *Disposal system.* Three systems are used to remove the gases:
 - passive, through wide-bore tubing to a terminal ventilator in the roof: disposal is dependent on wind direction.
 - assisted passive: the air-conditioning system extractor ducts remove the gases.
 - active: a dedicated ejector flowmeter or fan system is used. A low-pressure, high-volume system able to remove 75 l/min (with a peak flow of 130 l/min) is used.

Box 8.5 Anaesthetic machine checklist

- Anaesthetic machine including manufacturers' automated check
- Monitoring devices including function and alarm limits and volume settings
- Gas supply and suction
 - tug test
 - flowmeters (if applicable)
 - cylinders (filled and turned off)
 - suction clean and working
- Vaporisers
- Breathing systems
- Ventilator including alternative means of ventilating patient in event of failure
- Scavenging system
- Ancillary equipment including resuscitation equipment

Checking the Anaesthetic Machine

Absolute familiarity with the anaesthetic machine is fundamental for safe practice. It must be checked before an operating list, and eight items need inspection (Box 8.5). These checks are the responsibility of the anaesthetist. A checklist is normally attached to the anaesthetic machine.

Anaesthetic Machine

The manufacturers' (automatic) machine check should be performed.

Any information attached to the machine should be noted, for example, after routine maintenance by service engineers 'first user notices' may be attached.

Power Supply

Check that the machine and ancillary equipment are plugged in and switched on.

Monitoring Devices

Check that all devices (especially the oxygen analyser, pulse oximeter and capnograph) are functioning. Appropriate alarm limits and volumes must be set. Sampling lines should be unobstructed. The oxygen analyser is a fuel cell which is normally calibrated by a single-point calibration to room air – 21%. The sensor should be attached firmly to the common gas outlet.

Gas Supplies and Suction

This is to ensure that the correct gas supplies and connections exist within the machine, to check pressures and to stop the accidental delivery of a hypoxic gas mixture.

- Confirm that each pipeline is appropriately inserted into its gas supply terminal by undertaking a 'tug test'.
- Check that a reserve oxygen cylinder is available.

- Check that any other gases required are connected securely and have adequate supplies. A full oxygen cylinder has a pressure of 137×100 kPa and a nitrous oxide cylinder has a pressure of 52×100 kPa until only a quarter full.
- All pipeline pressure gauges should indicate 4×100 kPa.
- Check that the flowmeter works smoothly and that the bobbins, if present, move freely without sticking.
- Check that the anti-hypoxia device is working correctly.
- Check the emergency oxygen bypass control function.
- Check that suction is clean and working.

Vaporisers

- Check for correct mounting and that the back bar is locked.
- Check that the vaporiser is adequately filled.
- Turn 'on' – check for leaks – turn 'off' – recheck for leaks (check for leaks by occluding common gas outlet after opening oxygen rotameter).
- Check that the vaporiser is plugged in (if necessary).

Breathing Systems

- A new single-use bacterial/viral filter and catheter mount must be used for each patient.
- Check the configuration of the whole system, that it is patent and leak free.
- Check for leaks in the reservoir bag and that the adjustable, pressure-limiting expiratory valve does not stick and can be fully opened and closed.
- Check tightness of all connections (push-and-twist technique).
- Check the unidirectional valves in a circular system and in the exhaust system.
- Check colour of soda-lime.

Ventilator

- Check the ventilator is working and correctly configured.
- Check that a self-inflating bag and filled oxygen cylinder are immediately available. This is very important as an alternative means of ventilating the patient if there is a ventilator failure.

Scavenging System

- Check that it is switched on and functioning correctly and that the tubing is attached to the appropriate exhaust point of the breathing system or ventilator.

Ancillary Equipment

- Check that all laryngoscopes, intubation aids, forceps, bougies and so on are present and working.
- Appropriately sized facemasks, airways, tracheal tubes, supraglottic airways and connectors must be checked (including patency).

- Additional devices as required such as videolaryngoscopes, or difficult intubation trolley if required.
- Check availability and function of total intravenous anaesthesia (TIVA) equipment if appropriate.
- Resuscitation equipment is functioning and immediately available.

Recording

- Sign and date the logbook kept with the anaesthetic machine (confirm machine checked).
- Record on each patient's anaesthetic chart that the anaesthetic machine, breathing system and monitoring have been checked.

Conclusion

The novice anaesthetist must understand the basic workings of an anaesthetic machine and checking the machine must become a regular habit. However, just because the machine was checked in the morning, never assume that nothing can go wrong later in the day. Machines are moved, pipelines are stretched and vaporisers are changed. Remain vigilant. If in doubt about an anaesthetic machine ventilate the patient by means of the self-inflating bag and ask for advice.

Anaesthetic Breathing Systems

Anaesthetic breathing systems or circuits can be classified into two main groups:

- Circle systems

Box 8.6 Anaesthetic breathing circuit components

- Breathing hoses
- Bags
- APL valve
- Connections
- Carbon dioxide absorption
- Unidirectional valves

Box 8.7 Functions of bags in breathing systems

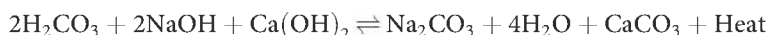
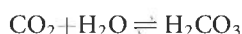
- Reservoir for gases. Although the machine can deliver flow rates of up to 10–20 l/min of gas, the patient has brief inspiratory flow rates of up to 30 l/min. To facilitate the delivery of this high flow rate, there must be a reservoir.
- Monitoring of ventilation.
- Facilitating manual intermittent positive pressure ventilation.
- Pressure-limiting function. The bag can distend to large volumes without pressure within the system increasing greatly. This safety feature avoids barotrauma to the patient's lungs if the pressure-limiting valve malfunctions or is omitted from the circuit.

- Semi-closed rebreathing systems

Each breathing system consists of several components: fresh gas, inspiratory and expiratory limbs, a pressure limiting valve and a reservoir bag. They may also have a carbon dioxide absorber and unidirectional valves (Box 8.6).

- Breathing Hoses – these are corrugated, 22 mm diameter, plastic tubes which are non-kinkable and non-compliant. They have a volume of 400–450 ml/m.
- Bags – these are made of latex free rubber or silicone. They are of 2 l volume in adult circuits and 500 ml volume in paediatric circuits. They have four functions (Box 8.7).
- Adjustable Pressure-Limiting Valves (APL) – these variable-orifice, variable-resistance devices vent excess gases and often have a scavenging facility. They consist of a light disc held onto a circular knife-edge by a light spring with tension. The spring is adjusted by a screw thread. When the valve is set fully open, the pressure to open the disc, and hence the valve, is only 0.1–0.2 kPa (1–2 cm H₂O), and minimal resistance to flow occurs. When the valve is closed, a safety device protects the patient by opening at a pressure of about 6 kPa (60 cm H₂O). This occurs at a gas flow of 30 l/min.
- Connections are achieved by 22 mm or 15 mm male-to-female fittings.
- Carbon dioxide absorption – this is an essential component of a circle system. Commonly used absorbents are soda-lime, baralyme (which has now been largely withdrawn) and the more recently introduced Amsorb. Soda-lime contains 80 per cent calcium hydroxide, 4 per cent sodium hydroxide, 1 per cent potassium hydroxide with the remainder water. It contains an indicator, which changes colour as the mixture is exhausted, and a hardener – silica gel. Ideally enough fresh soda-lime should be available for the whole operating session, as it is difficult to replace it in the middle of an operation.

Absorption occurs via the following chemical reaction:



The heat produced in this reaction which, along with the water liberated, provides useful warmth and humidity for the patient. Soda lime becomes exhausted when all hydroxides have become carbonates. Both absorbents absorb small amounts of anaesthetic agent. Sevoflurane reacts with soda-lime to produce Compound A which is a renal toxin but has not been found to be of clinical significance to humans.

Unidirectional valves ensure one-way flow in circle systems.

Circle Systems

The circle system has unidirectional valves to direct gas flow through hoses, a reservoir bag and soda-lime (Figure 8.2). Oxygen and the volatile vapour are added. As the inspired gases are free of carbon dioxide, the patient can rebreathe without adverse physiological effects. They enable the use of very low gas flows. The system is economical, conserves heat and moisture, minimises waste and pollution. However, to be efficient it must be free from leaks.

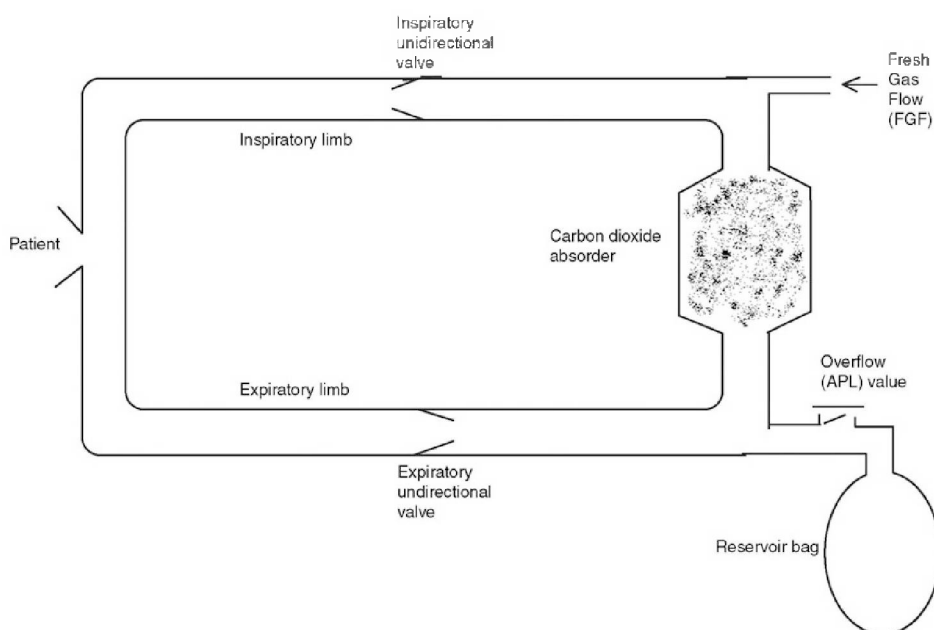


Figure 8.2 Circle system

Oxygen uptake from the lungs is relatively constant at 200–250 ml/min, but nitrous oxide uptake is initially high (500 ml/min), falling to 200 ml/min after 30 minutes, and 100 ml/min after 60 minutes. Therefore, hypoxic mixtures are possible at low flows – and this is one reason why an oxygen analyser must be incorporated into the system. Carbon dioxide and anaesthetic vapour analysis are also mandatory. Dilution of gases in the reservoir bag by nitrogen in the early part of the anaesthetic can occur – higher gas flows in the first 5 minutes are recommended. Higher fresh gas flows (greater than 3 l/min) at the beginning of anaesthesia also enhance uptake of anaesthetic agent and reduce the risk of awareness at the start of surgery when volatile agents are used.

Rebreathing Systems

Traditionally these systems had no separation of the inspired and expired gases, although in the newer coaxial systems partition of the gases occurs. Under conditions of low fresh gas flow or hyperventilation of the patient, rebreathing of carbon dioxide is possible. Flow rates of gases should be adjusted according to capnography. Classification of rebreathing systems was first described by Mapleson in 1954. There are six basic systems (Figure 8.3) and two involving a coaxial arrangement (Figure 8.4).

- **Mapleson A system:** this is also called the Magill system. Fresh gas flow should equal alveolar minute ventilation for spontaneous respiration and be 2–2.5 times the alveolar minute ventilation for intermittent positive pressure ventilation. This is the most efficient system for spontaneously breathing patients and the least efficient for intermittent positive pressure ventilation. The system is heavy with the valve in its traditional position and access is often difficult; because of this it was modified by Lack

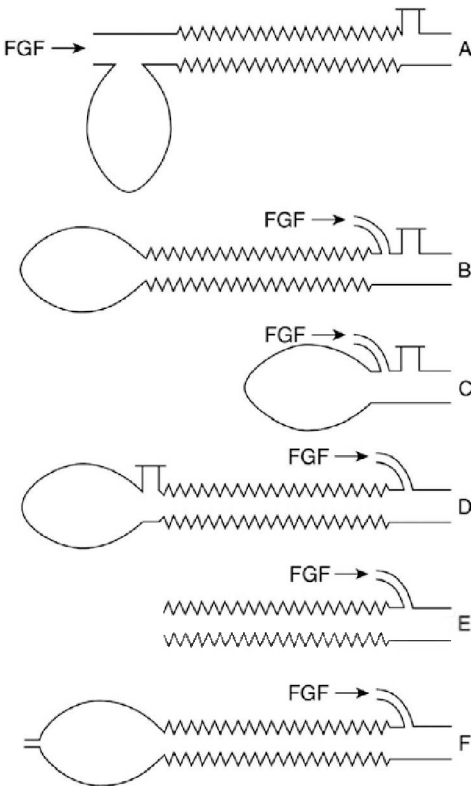


Figure 8.3 Mapleson classification of rebreathing systems. Arrows indicate direction of fresh gas flow (FGF)

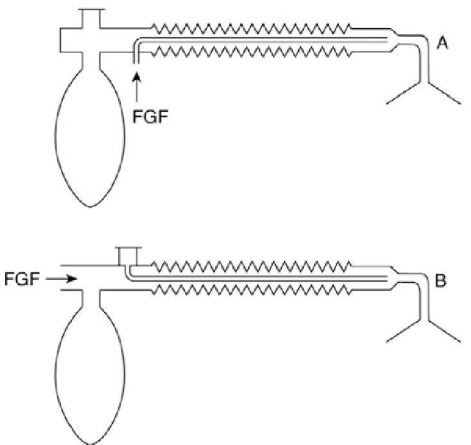


Figure 8.4 Coaxial systems (A) Bain and (B) Lack. FGF fresh gas flow

to incorporate the valve at the machine end of the circuit by an external tubing modification (parallel Lack circuit).

- Mapleson B and C systems: these are used infrequently, but the C is the basis of modern circuits useful for brief periods of manual ventilation during resuscitation.
- Mapleson D, E and F systems: these are also called T-pieces and differ only in the way they vent the gases. The Mapleson D is the most efficient for intermittent positive pressure ventilation.
- Bain circuit: this is a coaxial Mapleson D system with a 22 mm diameter outer tube and a 7 mm diameter inner tube through which gases enter. It is light, often disposable, has the gas entry and the expiratory valve at the machine end and has a clear outer tube to ensure that the inner tube is visible. Leaks or holes in the inner tubing cause rapid carbon dioxide rebreathing. To check for leaks in the inner tube, it should be occluded (fifth finger or 2 ml syringe). Oxygen flows of 5 l/min into the system will cause the anaesthetic machine backbar pressure-releasing alarm to blow as the occlusion pressure is transmitted along the machine. The reservoir bag should not distend. Flow rates using this system are high; at least 70–100 ml/kg/min and up to 2–3 times the minute alveolar ventilation are recommended.
- Mapleson E and F systems: these are also known as the Ayre's T-piece and the Jackson Rees modification. They have no adjustable pressure limiting valves and are used for children under 20–25 kg, again at flows of 2–3 times the minute alveolar ventilation. The open-ended reservoir bag of the Jackson–Rees modification was added to assist intermittent positive pressure ventilation rather than occluding the end of the Mapleson E system, although spontaneous ventilation can be monitored by its movement.

Conclusion

Anaesthetic breathing circuits may appear confusing initially, but the principles are simple. Modern monitoring facilities, particularly capnography and oxygen analysis, enable appropriate fresh gas flows to be used whatever circuit is employed. The breathing circuits are the most common site for gas leaks. Check carefully.

Ventilators

Ventilators used today can be considered as constant or non-constant generators of pressure or flow. The ventilator enables inspiration, cycles from inspiration to expiration and after allowing time for expiration including an expiratory pause, cycles back to inspiration. Power is needed for inspiration and the device may be driven by one of three methods: gas, electricity or a separate supply of compressed air or oxygen.

Flow-generated ventilators deliver a fixed total volume irrespective of alterations in airway resistance or lung compliance. In certain situations airway pressures may be sufficient to result in barotrauma.

Pressure generators deliver a preset pressure to the lungs. Both flow and tidal volume achieved will be dependent on airway resistance and lung compliance. Target pressure is adjusted to produce a reasonable tidal volume to avoid either atelectasis or volutrauma. Rate can be adjusted to control end tidal carbon dioxide.

Cycling can be controlled by time, volume, flow or pressure. Expiration is usually a passive process, but PEEP (positive end-expiratory pressures) can be applied. This has the benefit of improving oxygenation by helping to recruit alveoli and prevent atelectasis.

Ventilators now have a hypoxic guard, which means that it is impossible to deliver a mixture of gases that has a concentration of less than 25 per cent oxygen.

As increasing numbers of critically ill patients need to come to the operating theatre, there has been a demand for more sophisticated modes of ventilation. Many anaesthetic machines offer a wide range of ventilatory modes. Never use a ventilator unless you have received clear instructions about how it functions!

When using a ventilator you must ensure that the following are set appropriately for each individual patient:

- Inspired oxygen concentration
- Mode of ventilation (usually volume or pressure control ventilation, VC or PCV)
- Tidal volume (e.g., 4–6 ml/kg)
- Respiratory rate (e.g., 10–12)
- Inspiratory/expiratory (I/E) ratio (often 1:2)
- Pressure limit (usually < 30 mmHg)
- Positive end-expiratory pressure (PEEP) of 0–5 mm Hg
- Alarm settings are on and correct

When using any ventilator it is imperative that the following monitoring is available:

- Disconnection alarm
- Expired minute volume
- Capnography
- Inspired oxygen concentration beyond the ventilator
- Airway pressure

Other monitoring may be used as required. However, the basic monitoring ensures that the circuit is intact without leaks and that ventilation is adequate with a suitable inspired oxygen concentration. If in doubt, check by observation and auscultation that the lungs are ventilated.

Conclusion

Ventilators should never be used unless you have received clear instructions about their function. Beware of disconnections and ensure appropriate monitoring is in place.

Intravenous Anaesthesia

Programmable intravenous pumps can be used to deliver intravenous anaesthesia. These can be used alone as a TIVA technique or alongside volatile anaesthetic agents. Typical agents are propofol and remifentanyl. Target-controlled infusion pumps with advanced software have been developed. These allow patient characteristics (age, sex, weight and height) and the desired drug plasma concentration to be entered. A pharmacokinetic model is then used to control the pump to achieve the desired target concentrations of drug.

Ultrasound in Anaesthesia and Intensive Care

Ultrasound is a safe, cheap and portable imaging tool that has been used by radiologists for many years. The greater availability of ultrasound machines and an increasing number of clinical indications have now resulted in its widespread use in anaesthetics and intensive care. It is important that all clinicians understand the basic principles of how it works, are competent in its practical use and are aware of its limitations.

Basic Principles

- Sound waves are 'longitudinal' waves meaning that the molecules oscillate in a line in the same direction as the propagated wave (see Figure 9.1).
- Amplitude (A) is a measure of the maximum height of the wave.
- Period (π) is the time it takes for a wave to travel a distance of one wavelength.
- Wavelength (λ) is the distance covered in one cycle.
- Frequency (f) is the number of cycles per second, measured in Hz.
- Velocity (c) is the speed at which sound waves pass through a medium.

The wave equation relates frequency (f), wavelength (λ) and velocity (c):

$$c = \lambda f$$

where c = velocity, λ = wavelength, f = frequency

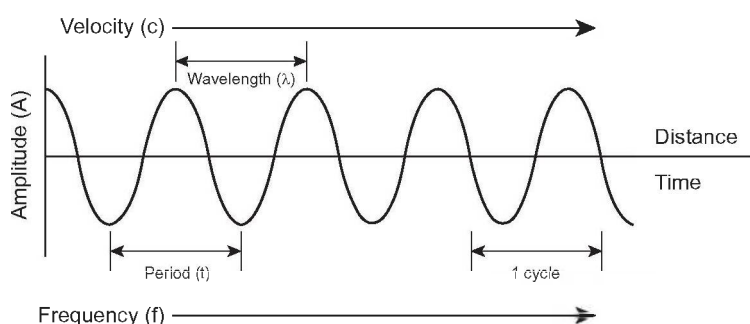


Figure 9.1 Sound wave showing amplitude (A), period (t), wavelength (λ), frequency (f) and velocity (c)

<https://avxhm.se/blogs/hill0>

Mechanism of Action

Medical ultrasound refers to high frequency sound waves usually in the range of 2–15 MHz. These frequencies are above the upper limit of the human audible range (20 kHz). The active element within an ultrasound probe or transducer is a piezoelectric crystal that vibrates when exposed to an alternating electrical input generating sound waves. These waves travel through the skin and come into contact with tissues of varying densities. The velocity or speed of the sound wave through each tissue varies according to its density and compressibility. Reflection of a wave occurs at an interface between tissues of different densities, such as fluid/soft tissue or tissue/bone. The crystal also acts as a receiver and works in reverse generating electrical signals from the returning reflected waves which are sent on for processing.

Using the speed of sound and the time taken to return, the scanner calculates the distance from the transducer to the tissue edge. These distances are used to generate two-dimensional (2-D) images of tissues and organs. The image can be displayed in a number of modes. The A or 'amplitude' mode reveals the location of structures only in the direction of the ultrasound beam and displays a single echo signal. It is not found on most machines today. The B or 'brightness' mode is the most commonly used mode for perioperative procedures. This image is composed of pixels with the brightness dependent on the intensity or amplitude of the echo returned. It provides a 2-D image and is used to assess organs in real time. The M or 'motion' mode displays movement of structures along a single line chosen by the operator and is used to evaluate heart wall or valve motion. Ultrasound can also be used in the Doppler mode. This analyses the frequency of the returning echo to determine relative motion using the Doppler effect.

Doppler

Doppler Effect

If a sound wave is reflected off a stationary object, the reflected wave has the same frequency as the transmitted wave. The Doppler effect occurs when the object is not stationary but moving in relation to the transducer. In this scenario, there is an apparent change in the frequency of the reflected wave due to the relative motion between the transmitter and the receiver. If the object is moving towards the receiver, it will appear to increase. In contrast, if the object is moving away from the transmitter, the perceived frequency is decreased. In Doppler ultrasound, the transducer transmits sound waves at a given frequency towards a moving object, such as a red blood cell. As the reflection returns to the transducer, the frequency will be altered based on the speed and direction of the travelling red blood cell. This is referred to as the Doppler frequency shift. This principle is used as a non-invasive method of measuring blood velocity and flow, for example measurement of cardiac output.

Doppler Modalities

- **Colour Doppler** – this adds information about the velocity of moving objects onto the B-Mode image. It shows the direction of flow towards (red) or away (blue) from the transducer.

- Colour Power Doppler – this adds information about the energy of the returning Doppler signal onto the B-mode image. It does not contain any information about direction or velocity of flow.
- Spectral Doppler – used to describe pulsed wave Doppler and continuous wave Doppler imaging. Returning signals undergo machine-automated Fast Fourier analysis to produce graphical representations of flow velocity over time.

Image Quality

The image obtained is dependent on the strength and quality of the emitted and returning signal. The ultrasound wave is reduced in intensity or attenuated as it travels through tissue layers. The attenuation coefficient of a tissue represents the degree of attenuation encountered. The higher the coefficient, the more attenuated the ultrasound wave is by the specified tissue. Bone has a very high attenuation coefficient and severely limits transmission. There is good transmission by water and blood which have low coefficients.

Attenuation is determined by:

- Amplitude of the original signal. The stronger the ultrasound waves emitted from the probe (the better the probe) the more signal will be returned.
- Absorption by tissues reduces the amount available for reflection.
- Reflection and scattering. Some surfaces are better at reflecting the ultrasound wave than others. Smooth surfaces tend to reflect better than rougher surfaces which scatter waves reducing those reflected to the probe.
- Acoustic impedance. The amount of reflection at any interface is determined by the difference in acoustic impedance (the resistance of a tissue to the passage of ultrasound) between the two tissues. The greater the mismatch, the greater the reflection. Bone produces a strong reflection due to its extremely high acoustic impedance relative to other body tissues. Air also produces a strong reflection as it has an extremely low acoustic impedance relative to other body tissues, hence the need for conducting gel between the skin and transducer to eliminate air pockets.
- Refraction. This occurs when the sound wave contacts the boundary of tissues at an oblique angle. This causes the reflected sound beam to travel in a direction that is away from the transducer resulting in a weaker signal and a darker image.
- Diffraction. This refers to the spread of a beam as it moves further from its source and its intensity decreases.

Echogenicity

The brightness of the image is dependent on the amplitude of the echo returned. Strong reflections produce very bright or hyperechoic images. Tissues that appear hyperechoic include bone, air and fascia. Weaker diffuse reflections such as from solid organs, muscle and some nerves appear grey or hypoechoic. Fluid or blood-filled structures appear dark or black (anechoic) as there is no significant reflection.

Resolution

There are two types of resolution, spatial and temporal.

- Spatial resolution describes the ability to distinguish between two points as separate entities on the screen and depends on pulse duration. It determines image clarity and has two aspects, axial and lateral resolution. Axial resolution describes whether two objects are discernible in a direction parallel to the sound beam. Lateral resolution refers to two objects in a direction perpendicular to the beam. The higher the emitted frequency, the lower pulse duration and the better the axial resolution. Lateral resolution is also influenced by the beam width.
- Temporal resolution describes the ability to distinguish between events in time such as valve movement during the cardiac cycle. It depends upon the rate at which consecutive images are generated and viewed.

Equipment

Ultrasound machines come in a variety of sizes and with a range of capabilities from basic to high quality, sophisticated machines. They include small hand-held devices, laptops and cart-based machines. Whilst this has provided greater versatility and portability of ultrasound machines, it can be confusing for a novice. Familiarity with the machine and its capabilities before use is vital. Most machines have the following components:

- Transmitter – emits a voltage of prescribed duration generating pulses of energy.
- Transducer – converts this electrical energy into sound waves and vice versa.
- Receiver – detects, compresses and amplifies signals returning to the transducer.
- Screen – displays the signal.
- Memory – stores images.

Box 9.1 Examples of types of ultrasound probes

- Linear probes:
High frequency (6–15MHz)
High resolution, but with higher frequency there is more attenuation. Best limited to superficial structures (1–6cm) depth, e.g., nerves or blood vessels
Good for vascular access, nerve blocks, e.g., brachial plexus
- Curvilinear probes:
Low frequency (2–5MHz)
Able to image deeper structures (10–20cm), but with a low resolution
Useful for large or deep structures, e.g., sciatic nerve, abdominal, pelvic organs
- Phased:
The lowest frequency (1–3MHz)
Better spatial depth
Useful for echocardiography



Figure 9.2 Examples of the curvilinear and linear probes.

Ultrasound Transducers

A variety of transducer probes are available as shown in Box 9.1 and Figure 9.2. Optimal imaging requires the most appropriate probe for that particular procedure. Higher frequencies allow better resolution of detail but have less tissue penetration. Lower frequencies are better for deeper structures but give poor spatial resolution. During ultrasound guided procedures, the ideal probe is usually the one with the highest frequency that allows adequate penetration. For example a probe with a frequency of 20 MHz is commonly used to visualise insertion of needles and catheters and a probe with a frequency of 3 MHz is normally used to visualise the kidneys. In addition, access may be limited by the size of the probe; smaller probes may be needed in certain anatomical locations and patients.

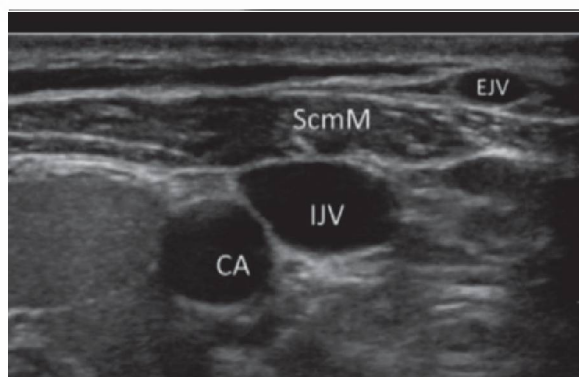
Ultrasound Controls

Most machines will have preset imaging programmes such as ‘vascular’ or ‘nerve’ to optimise visibility and picture quality. However fine tuning is still required by adjusting:

- Depth – this is adjusted to place the target tissue in the centre of the imaging field.
- Focus – this adjusts the beam to be at its narrowest at the desired depth.
- Gain – the degree of receiver amplification is called the gain. By increasing the gain the returning signal is amplified. However, this will increase the brightness of the entire image, including the background noise. The use of time gain compensation (TGC) can selectively amplify the weaker signals returning from deeper structures.

Structures can be visualised using either an in-plane (longitudinal) or out-of-plane (transverse) approach (see Figure 9.3). These views can be used to guide needle placement by visualising the needle as it advances toward the desired target. The out-of-plane view is easier to obtain and better for identifying veins and arteries and their orientation to each other. However, identifying a needle tip in cross section can be difficult as it appears as an echogenic or white dot. The in-plane (longitudinal) view is technically more difficult to obtain. However it shows the needle longitudinally and the entire needle can be viewed as it approaches and enters the vein to help avoid incorrect placement.

A. Out-of-plane ultrasound view of the right internal jugular vein
left is the medial side and right is the lateral side



B. In-plane ultrasound view of the internal jugular vein



Figure 9.3 Ultrasound Image of the out-of-plane (A) and in-plane (B) view of the internal jugular vein in an adult patient

CA, carotid artery; EJV, external jugular vein; IJV, internal jugular vein; ScmM, sternocleidomastoid muscle

A. Out-of-plane ultrasound view of the internal jugular vein

B. In-plane ultrasound view of the internal jugular vein

Applications

Ultrasound enables the rapid acquisition of high-resolution images of anatomic structures in real time. Point of care ultrasound (POCUS) refers to its use at the patient's bedside to diagnose or assist in performance of a procedure. Typically this is confined to a rapid qualitative scan that is goal orientated. Potential uses include the rapid diagnosis of causes of perioperative hemodynamic instability such as hypovolaemia versus cardiac dysfunction. Other perioperative uses of ultrasound include guidance for regional anaesthesia and vascular cannulation, examination of pulmonary, gastric and other abdominal structures and echocardiography of the heart and great vessels.

Vascular Access

- Ultrasound guided vascular access is associated with a higher first pass success and fewer complications. This led to a NICE recommendation that ultrasound guidance should be used for insertion of central venous catheters into the internal jugular vein and it should be considered in most clinical circumstances where central venous access is necessary, both electively and in emergency situations. Ultrasound guidance is also useful in patients with difficult venous access and to guide arterial line insertion.

Regional Anaesthesia

- Ultrasound allows detection of anatomical variants, direct observation of target nerves and the surrounding structures, real-time needle guidance and observation of the spread of local anaesthetic around the nerve. Its use is associated with higher success rates, the use of smaller volumes of local anaesthetic solutions, fewer complications and improved patient comfort.

Gastric Ultrasound

- Ultrasound can be used for assessment of gastric content and volume to minimise the risk of aspiration.

Airway Assessment

- Airway ultrasound can be used to visualise most structures except the posterior pharynx and tracheal wall aiding airway evaluation.

Thoracic Ultrasound

- The use of ultrasound for assessing and treating thoracic pathology in intensive care has increased significantly. It can distinguish between effusion, consolidation and collapse. It can diagnose pneumothorax and pulmonary oedema. It may also be used to guide invasive procedures such as chest drain insertion and percutaneous tracheostomy.

Cardiac Ultrasound

- Transthoracic echocardiography (TTE) may be used to evaluate valvular abnormalities, assess biventricular function, diagnose pericardial tamponade and causes of haemodynamic instability. Transoesophageal echocardiography (TOE) gives more detailed intraoperative information.

Conclusion

Advances in ultrasound technology and development of technical skills and have significantly improved the safety and efficacy of vascular access and regional anaesthesia techniques. The use of ultrasound guidance as the gold standard has played a key role in this. Its applications continue to expand. However, it is a skill that must be acquired through training and practice and to understand any image a knowledge of the underlying anatomy is essential.

Monitoring in Anaesthesia

An important source of anaesthetic-related morbidity and mortality remains human error. All anaesthetists have tales of drug administration errors and ‘near-misses’; those anaesthetists who claim never to have problems are either doing insufficient work or are economical with the truth. A critical incident register is recommended in every anaesthetic department. A critical incident is an untoward event, which, if left uncorrected, would have led to anaesthetic-related mortality or morbidity. It includes many events ranging from disconnection of the breathing circuit to unrecognised oesophageal intubation and severe bronchospasm. It is hoped that better monitoring will reduce the incidence of these complications.

There should be appropriate monitoring wherever anaesthesia is conducted, whether it is in the anaesthetic room, the operating theatre, the psychiatric department, the X-ray department or a dental surgery.

Indeed, anaesthetising ‘away from home’ outside the operating theatres demands particular care and appropriate monitoring must be present.

Full monitoring has three requirements, as shown in Box 10.1.

Anaesthetist

The anaesthetist must be present throughout the surgical procedure, and readily available to recovery room staff until the patient leaves the theatre complex. This responsibility is solely the anaesthetist’s, and is applicable in general and regional anaesthesia, and also in some sedation techniques where the anaesthetist is involved.

An adequate record must be made of the whole anaesthetic process, from the induction to full recovery of the patient. Errors can occur for a variety of reasons, ranging from inexperience and lack of training to tiredness, boredom and inattention. Vigilance in an anaesthetist is a function of self-motivation.

The novice anaesthetist should acquire rigorous monitoring habits. Tracheal intubation must be confirmed every time, and the equipment, the anaesthetic machine and circuitry

Box 10.1 Anaesthesia monitoring requirements

- Presence of anaesthetist
- Checking and monitoring the anaesthetic equipment
- Patient monitoring
 - clinical
 - technical

checked as a routine. Post-operative visits to assess a patient's progress are salutary and give an opportunity to improve aspects of care, including post-operative analgesia and the prevention of nausea and vomiting.

Checking and Monitoring Equipment

Checking and monitoring the function of anaesthetic equipment has already been discussed in preceding chapters. Two key features must be emphasised – the oxygen supply and the breathing system.

Oxygen Supply

The gas supply to the oxygen flowmeter must contain a low-pressure warning device and have an audible alarm. Check the alarm limits. The analyser must be in such a position as to continuously monitor the composition of the gas mixture delivered to the patient at all times.

If hypoxic mixtures can be delivered (most old machines), then a device which continuously monitors the concentration of oxygen delivered to the patient must be fitted, and this too must have an audible alarm.

Breathing System

If faults exist in the circuit, these are best detected by monitoring the expired volume and the end-tidal carbon dioxide concentration and by measuring the airway pressure (high-pressure alarm). Clinical observation of the reservoir bag may reveal leaks, disconnections and over-distension from high pressure. During mechanical ventilation continuous measurement of the airway pressure, the expired volume and the oxygen and carbon dioxide concentrations is mandatory (see Chapter 9).

The alarm limits for equipment should be reset for each case and alarms should be turned ON (not turned off because the limits are being exceeded for a particular patient, but are not causing concern).

Tracheal Tubes and Supraglottic Airways

Increasingly pressures on tracheal tube cuffs and some types of supraglottic airways are monitored. Tracheal cuff pressure should be less than 25 mm Hg and cuffs should not be over-inflated. Tracheal mucosal ulceration can result from over-inflation which results in a post-operative sore throat. Occasionally, the mucosa will tear, and this can cause a pneumomediastinum.

Vapour Analyser

A vapour analyser is essential if a volatile anaesthetic or nitrous oxide is used.

Infusion Devices

Check any infusion device is working and set the alarms (infusion pressure and infusion limits). Ensure the intravenous cannula is patent and it should be visible throughout.

Alarms

Set and check all alarms especially ventilation pressure alarms which give warning of high pressures in the system as well as leaks and disconnections. All equipment should be calibrated appropriately. Before use all alarms should be set to patient-specific values and audible sounds enabled.

Monitor Displays

Clear visibility of displays is essential and if using non-invasive blood pressure monitoring then measurements should be made <5 minutes apart.

Patient Monitoring

Clinical

The continuous observation of the patient's colour, chest movement and pattern of respiration, absence or presence of sweating and lacrimation, reactions of the pupil, palpation of a peripheral pulse and use of a stethoscope provide essential basic monitoring of the patient. Much useful information can be obtained by simple observation, palpation and auscultation – arts that are rapidly disappearing from anaesthesia. Observe the movement of the reservoir bag in spontaneously breathing patients and its feel may give an indication of any changes in compliance.

Box 10.2 Patient monitoring devices (essential)

- Cardiovascular
 - heart rate
 - electrocardiogram
 - non-invasive arterial pressure (<5 min cycling)
 - pulse oximetry
- Respiratory
 - respiratory rate
 - inspired and end-tidal carbon dioxide concentration (capnography)
 - inspired and expired oxygen, nitrous oxide and volatile agent
 - airway pressures
- Muscle relaxation
 - peripheral nerve stimulator
- Gas analysis and minimum alveolar concentration (MAC)
- Depth of anaesthesia
 - Processed EEG monitoring – should be used when TIVA is administered with neuromuscular blocking agents
- Temperature for any procedure >20 min
- Blood glucose monitoring – should be readily available

Box 10.3 Specialised patient monitoring devices

- Invasive arterial pressure
- Central venous pressure
- Cardiac output (oesophageal Doppler or directly from an intra-arterial waveform)
- Cerebral oximetry
- Motor and Sensory Evoked Potentials
- Urine output
- Measurement of blood loss
- Biochemical analysis: pH, arterial gas analysis, electrolytes
- Haematological analysis: haemoglobin, coagulation studies

Technical

The systemic circulation and ventilation need continuous monitoring in all forms of anaesthesia. If neuromuscular blocking agents are used, a peripheral nerve stimulator must be used. The devices used routinely are shown in Box 10.2. In specialised surgery, facilities for further monitoring are required (Box 10.3).

Electrocardiogram (ECG)

The ECG needs special emphasis because it is important to remember that electrical activity can exist even though there is no adequate cardiac output. Its value lies principally in monitoring changes in heart rate and in the diagnosis of arrhythmias. ST segment changes can also be noted.

Pulse Oximetry

Oximetry depends upon the differing absorption of light at different wavelengths by the various states of haemoglobin. Oxyhaemoglobin and reduced haemoglobin differ at both the red and infrared portions of the spectrum. The absorption is the same at 805 nm, the isobestic point. A pulse oximeter has two light sources on one side of the probe and a photodiode which generates a voltage when light falls upon it. The two emitting light sources are at 660 nm red (visible), and at 800 nm infrared (not visible).

The tissues absorb light but enough is transmitted to reach the photodiode. The arrival of the arteriolar pulsation with oxygenated blood alters the amount of red and infrared light transmitted through to the finger. This change in arteriolar pulsation is calculated by a microprocessor and the amount of oxygenated blood in the tissue deduced. The size and the shape of the arteriolar pulsation is shown as a plethysmographic trace. You must be able to see a pulsatile trace to rely on the oximeter reading.

The sigmoid shape of the oxygen dissociation curve means that saturations of above 90% show adequate tissue oxygenation.

Oximetry is unreliable in the following instances:

- excessive movement
- venous congestion

Box 10.4 Causes of low oxygen saturation

- Oxygen supply
 - oxygen flow turned on?
 - machine delivering oxygen? (oxygen analyser)
 - vaporiser fault?
- Oxygen delivery to patient
 - circuit assembled correctly?
 - airway patent, NO OBSTRUCTION?
 - tracheal tube sited correctly?
 - DISCONNECTION?
- Lung function
 - normal airway pressure?
 - tracheal tube in right main bronchus? bronchospasm?
 - pulmonary oedema, pneumothorax?
- Haemoglobin
 - unrecognised haemorrhage?
 - hypovolaemia?
- Heart
 - adequate blood pressure?
 - arrhythmias?
- Tissues
 - septicaemia?

- excessive illumination
- race
- nail polish/false nails
- intravenous drugs: methylene blue, indocyanine green
- carbon monoxide poisoning

A low oxygen saturation ($\text{SpO}_2 < 90\%$) demands an immediate response. Oxygenation of the tissues depends on the inspired oxygen concentration, lung function, haemoglobin concentration and cardiac output. The main causes of low oxygen saturation are shown in Box 10.4. If necessary, deliver 100% oxygen to the lungs while determining the cause of the hypoxaemia and starting appropriate treatment.

The most common cause of low oxygen saturation is an obstructed airway, and this should be excluded before other diagnoses are considered.

Box 10.5 Common causes of high and low PaCO₂

- Low
 - hyperventilation
 - low cardiac output: hypotension, embolism (gas or blood)
- High
 - hypoventilation
 - rebreathing carbon dioxide: circuit failures, exhausted soda lime
 - hypermetabolic states: malignant hyperthermia

Capnography

Capnography is used to measure carbon dioxide. This utilises the principle of infrared absorption. When infrared light falls on a molecule, it enhances the molecule's vibrational energy and the infrared light is absorbed by the molecule. The amount of infrared light absorbed at a specific wavelength is proportional to the amount of carbon dioxide present in the gas mixture.

In the presence of a stable cardiac output, arterial carbon dioxide tension is related inversely to alveolar ventilation:

$$\text{PaCO}_2 = 1/\dot{V}_A$$

Capnography should also always be used when providing procedural anaesthesia, this may be in theatre or outside of it, for example in the emergency department.

Common causes of high and low PaCO₂ are shown in Box 10.5.

For more details on confirming tracheal intubation using capnography see Chapter 3.

Blood Pressure Monitoring

Blood pressure can be monitored non-invasively using automated oscillometric cuffs or invasively using an arterial line. The use of an arterial line allows for standard beat-to-beat blood pressure monitoring and is particularly useful in high-risk cases and during long operations.

Cardiac Output Monitoring

Although blood pressure gives useful information, measurement of blood flow (i.e., cardiac output) have become common practice in anaesthesia and critical care. Cardiac output is derived from monitoring devices that measure several parameters associated with the central circulation.

Traditionally, techniques to measure this would involve a pulmonary artery floatation catheter, such as a Swan-Ganz catheter, which is known to be the gold standard due to its accuracy. Over the recent decades, there has been a rapid expansion in the use of cardiac output measurement and the devices available. These are particularly useful as they can aid in the optimisation of haemodynamics and O₂ delivery and facilitate goal-directed fluid therapy. Arterial pulse contour analysis, using Pulse Contour Cardiac Output (PICCO) and <https://avxhm.se/blogs/hill0>

Lithium Diluted Cardiac Output (LIDCO), uses the pulsatile component of the arterial waveform to measure cardiac output providing continuous beat-to-beat monitoring. PICCO is calibrated using a thermodilution technique, whilst LIDCO is calibrated using a Lithium dilution technique. Transoesophageal Doppler measures blood flow velocity using the Doppler effect and is another now less commonly used form of invasive cardiac output monitoring.

Box 10.6 EEG frequency table bands		
Band	Frequency range (Hz)	Clinical state
delta	<3	Unconscious, non-REM sleep
theta	4–7	Drowsy
alpha	8–12	Conscious, but relaxed
beta	>13	Alert and focused
gamma	>40	High level processing

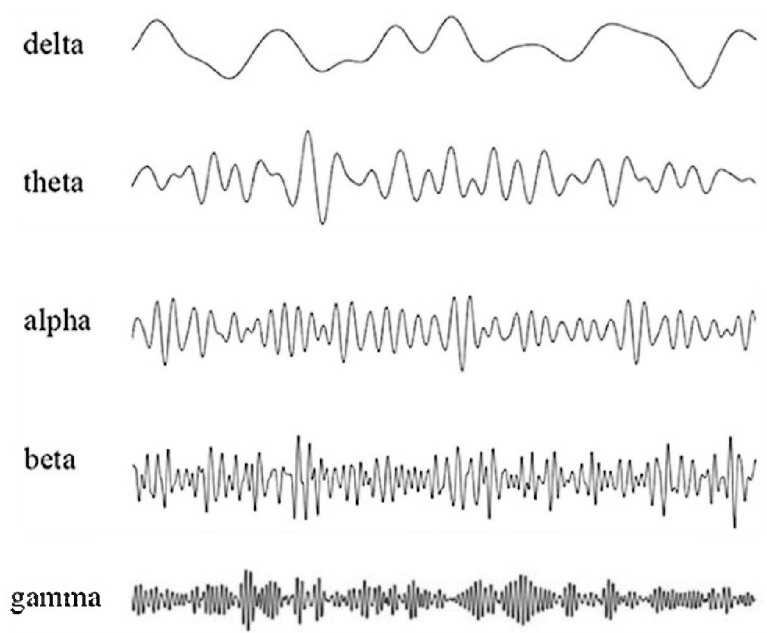


Figure 10.1 Examples of pEEG waveforms

Depth of Anaesthesia Monitoring

Processed Electroencephalogram (pEEG) Based Monitoring

Processed EEG monitoring can measure cerebral activity and is used as a general indicator of cerebral perfusion and metabolic activity. The pEEG displays an electrical signal based on the sum of the excitatory and inhibitory postsynaptic activity and can vary in amplitudes between 1 and 500 nanoV. Processed EEG signals can be classified into five frequency bands (Box 10.6, Figure 10.1). The pEEG of an awake patient would display a low amplitude and high frequency, whilst anaesthesia would cause the reverse to both.

Bispectral index (BIS) monitoring is commonly used to monitor the depth of anaesthesia when using TIVA, but also during the use of volatiles. It functions by using an algorithm to calculate an index derived from the patient's EEG. The BIS index ranges from 0 to 100, with 0 being equivalent to a silent EEG (isoelectricity) and 100 the awake state. During general anaesthesia the BIS index should be kept between 40 and 60. Certain agents may affect the reliability of BIS, such as ketamine and nitrous oxide. In addition to minimising awareness, it can indicate excessive anaesthetic depth too. The latter is suggested by a very low BIS index as well as other indices such as a high 'burst suppression ratio' implying significant periods of low/isoelectric EEG activity.

Minimum Alveolar Concentration (MAC)

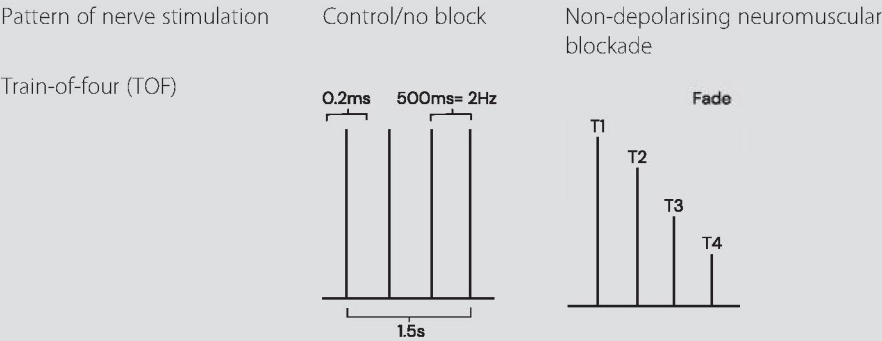
When using volatiles the MAC is used as a measure of anaesthetic agent potency and determines how much volatile anaesthetic is required to keep the patient asleep. The MAC is defined as the concentration of volatile present in the alveoli which would keep 50% of people unresponsive during a surgical stimulus, that is to say, a knife to the abdomen! This should be age-adjusted and always monitored when delivering a volatile anaesthetic.

Neuromuscular Monitoring

Commonly this is monitored using by electrical stimulation of a peripheral nerve. Clinically, surface electrodes are placed on a peripheral nerve which is stimulated by an electrical current leading to a muscle twitch. A variety of stimulator pulse patterns exist with the most used being the 'Train of Four' (TOF) in which four identical stimuli are delivered at 2 Hz (Box 10.6). A common placement for the electrodes is over the ulnar nerve, facial nerve or posterior tibial depending on the type of surgery and access to the patient. The negative (black) electrode is placed distally. The use of non-depolarising neuromuscular blocking agents will cause a reduction in the height of the twitches as it is linked to its receptor occupancy. Modern neuromuscular monitoring involves the ability to quantify the degree of neuromuscular blockade using accelerometry or electromyography (EMG).

For intraoperative block, a simple visible TOF count of 1–3 is usual (although some use much deeper levels of block). However, at the end of surgery, prior to extubation, confirmation of reversal of block is vital. As a consensus, the ratio of the fourth to the first twitch (TOF ratio) should be at least >90% to determine if the patient has adequate respiratory function for extubation, as 'fade' is minimal (see Box 10.7). These quantitative methods of accurately measuring TOF ratio are now the gold standard for confirmation of safe reversal of neuromuscular block. Other qualitative modes exist such as tetanic stimulation (which can be useful for the detection of deep residual blockade) and double burst stimulation but

Box 10.7 Pattern of TOF nerve stimulation



are much less reliable. Trying to guess a TOF ratio by simple observation (i.e., without measuring) is very unreliable!

Recovery Area

Full monitoring equipment including pulse oximeter, NIBP, ECG, and capnography if a tracheal tube or supraglottic airway are still in situ or there is deep patient sedation, and temperature, must be available in the recovery room. This standard must be maintained and be available for the transportation and transfer of patients to the recovery area.

Conclusion

The most important monitor during any anaesthetic procedure is the presence of a trained, vigilant anaesthetist. Under no circumstances must you ever leave the theatre while a patient is under your care. Careful, repetitive clinical observation of the patient is the next essential procedure, followed by the appropriate use of monitors to assess the respiratory and cardiovascular systems. These principles apply to all surgical procedures. There are ‘small operations’ but there is no such thing as a ‘small anaesthetic’.

Minimising Risk

At first glance, anaesthesia may look complex, nerve-racking and somewhat risky but modern anaesthesia is safe, due to a number of reasons including anaesthetic training, preoperative preparation, perioperative monitoring and appropriate levels of postoperative care.

For healthy patients undergoing minor surgery the risks to life are very small (less than 1:100,000) but as both the surgical complexity as well as the comorbidities of patients increase risk clearly increases. Increasing risk sets the scene for increased side effects, serious complications and death, and sadly many of these complications lead to long-term morbidity with some patients never returning to their preoperative level of health. With about 1.5 million major surgical procedures undertaken annually in the UK and about 25% of patients developing a complication this is a huge area. Very serious avoidable events are categorised as 'never' events, but with more than one per day reported in the UK and some hospitals producing nearly one per month they are certainly not never events! The never events relevant to our practice include:

- Wrong side block
- Medication administered by wrong route
- Wrong blood transfused
- Insulin overdose
- Misplaced nasogastric or orogastric tubes

There are many factors, other than the patients and their surgery, that contribute to risk for both patients and staff, within the perioperative setting:

Human Factors

Teamwork, task management and situational awareness are all recognised as important issues. Moreover, fatigue and working under pressure, which are common themes, add further to risk. Everyone is encouraged and empowered to speak up if they witness practices that are incorrect or dangerous.

Organisational

Issues surrounding hospital systems, working environment (which may be cramped or have no chairs, for example), faulty equipment and monitoring and the introduction of unfamiliar IT systems are all areas that can contribute to risk.

Assessing Risk

There are numerous risk scoring and risk prediction models, as outlined in the list below. A risk to life calculated to be greater than 5% suggests a patient should be admitted to ICU postoperatively.

- ASA classification (American Society of Anesthesiologists)
 - P POSSUM (Portsmouth Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity)
 - SORT (Surgical Outcome Risk Tool)
 - Revised Cardiac Risk Index (RCRI)
 - ACS-NSQIP (American College of Surgeons National Surgical Quality Improvement Programme)
 - SAS (Surgical Apgar Score)
 - NELA (National Emergency Laparotomy Audit)
- Other approaches to assess risk include:
- Functional capacity testing, for example, cardiopulmonary exercise testing
 - Biomarkers

A Practical Approach to Perioperative Risk Reduction

General

The introduction of the WHO surgical check list and bundles of care or protocols help to reduce variation and risk (e.g., sepsis, insertion of central lines, epidurals) and errors in practice. Many hospitals also have quick reference handbooks for the more common emergencies that may occur so that a structured check list can be followed if the event of anaphylaxis, cardiac arrest, high airway pressures and so on.

Preoperatively

Delaying surgery where appropriate to allow optimisation. This may be to address some of the quicker fixes, for example, to treat infections, cardiorespiratory and renal optimisation, treat anaemia (e.g., IV iron) and anticoagulant therapy management, including bridging. Longer-term fixes include diabetes control, rationalising preoperative opioids, management of smoking (including nicotine replacement patches), excessive alcohol intake, poor nutrition and obesity. Not all of these can be addressed within the preoperative time frame. Finally, prehabilitation (providing advice on increasing exercise, with nutritional and psychological support) is becoming popular.

Intraoperatively

Major areas for all anaesthetists

- Serious airway problems and in particular unrecognised oesophageal intubation, approximately 1 in 1,000,000 in theatre but much higher in ICU (1 in 15,000) and in ED (1 in 10,000).
- Prevention of end organ injury. Ensuring adequate mean arterial blood pressure (MAP), blood flow and oxygenation to vital organs, particular the brain, heart and kidneys is important, particular in those with limited reserve.
- Lung protection, in particular minimising the risk for postoperative pulmonary complications such as prevention of aspiration and adequate reversal of neuromuscular blockade. Ventilation strategies in terms of tidal volume and positive end expiratory

pressure (PEEP) are discussed in Chapter 8 to minimise under ventilation or over ventilation (causing barotrauma).

- Prevention of confusion and delirium in the elderly and frail. A multifactorial approach included adequate MAP but also avoiding drugs that are known to cause confusion.
- Care with areas such as intraoperative warming, general care of the unconscious patient prevention of dental damage, cuts to lips, ensuring patient secure on the operating table, padding to prevent nerve palsies and so on.

Postoperatively

Providing effective and safe analgesia is important and in particular care is required for patients who are receiving infusions of local anaesthetics and/or opioids as well as other drugs such as nonsteroidal anti-inflammatories. The correct prescribing of IV fluids is crucial too. The postoperative time becomes an increasing focus within perioperative medicine, and includes appropriate oxygen therapy, early eating, drinking and mobilising and thromboprophylaxis. Hospital beds with the correct equipment and adequate skill mix of trained staff are always an issue, but we have to ensure that patients are in the correct location for their care (e.g., Level 2 not a general ward). Early detection of medical and surgical complications is paramount and most hospitals will use some form of early warning scores (EWS) to rapidly identify the deteriorating patient

Finally . . .

The planned surgery may not be the most appropriate treatment for some patients. Sometimes lesser surgery (with therefore less risk) or indeed no surgery at all may be the best course of action for patients with limited reserve, frailty and so on. These are usually complex decisions, and shared decision-making (SDM), well in advance of the day of surgery, is crucial amongst surgeons, anaesthetists and intensivists and others (e.g., oncologists and other physicians). ‘Surgical regret’ is not a rare phenomenon whereby the patient wishes they had not had surgery.

Simple issues such as performing all checklists, meticulous airway control and venous access, good monitoring including depth of anaesthesia (and also including continual anaesthetic presence in theatre) and familiarity with equipment are straightforward ways to reduce risk. In spite of the above, crises and complications do occur. Now read on . . .

Crises and Complications

As soon as you are capable of assessing and controlling the airway, ventilating the lungs and establishing vascular access, it is likely that you will be given a bleep. As the 'on-call' anaesthetist, your problems have now started, as you will be expected to assess and start the management of a large number of anaesthetic problems around the hospital.

In this section of the book we describe a variety of crises and complications. Some are common, such as cardiac arrest and massive haemorrhage, whereas others, such as malignant hyperthermia, are rare. Unfortunately, patients cannot be relied on to respect your lack of experience, and they have the uncanny habit of keeping the most unusual complications for the most junior members of staff at the most unsocial hours.

Some of the crises are caused by you, the anaesthetist. If you cause the crisis you must have the knowledge and skills to manage it.

Cardiac Arrest

It is vital that you know how to manage a cardiac arrest. In the operating theatre, and often on the wards, you will be expected to manage these patients and be responsible for making decisions. Perioperative cardiac arrest has an overall incidence of approximately 1 in 3,000 anaesthetics. However, the majority of these occur in older, frailer patients (1 in 1,200), and in high-risk, urgent or emergency surgery.

The causes of cardiac arrest in the operating theatre can be broadly classified as follows:

- Medical diseases – usually due to underlying cardiac disease.
- Surgical causes – usually due to haemorrhage (occult or massive), occasionally vagal responses to surgical traction.
- Anaesthetic causes – usually secondary to hypoxia and hypercapnia, typically resulting from airway problems, for example, failure to secure the airway and ventilate the lungs (cannot intubate, cannot oxygenate scenario) or unnoticed disconnection of the anaesthetic circuit. Complications of vascular access, for example, tension pneumothorax after central venous cannulation can result in cardiac arrest. Rarely, drug errors, overdoses or an adverse drug reaction can lead to cardiovascular collapse.

Vigilance can often prevent these disasters. Distractions from mobile phones and the internet prevent correct vigilance.

Tracheal Intubation

The tracheal tube must be correctly positioned and secured. When there is no cardiac output, no carbon dioxide is produced; the capnograph is not helpful in assessing correct positioning of the tracheal tube. Visualisation of the tube passing through the laryngeal opening is critically important, and auscultation is used to ensure it is placed in the trachea and not the right main bronchus. Videolaryngoscopy enables other members of the team to visualise correct placement and assist when difficulties arise.

The capnograph may be a guide to the adequacy of the cardiac output when cardiopulmonary resuscitation (CPR) is undertaken.

Defibrillation

Whenever you start to work in a new environment you must know where the defibrillator is kept and how it works. It should be tested every day without fail. A defibrillator is a capacitor and thus stores electrical charge. Usually, it has four primary controls:

- on
- charge

- defibrillate
- synchronisation

Oxygenation

It is essential that the lungs are ventilated with 100% oxygen. An oxygen analyser should be attached to the anaesthetic machine to confirm the nature of the fresh gas flow. (Check that the vaporisers are turned off.) If doubt exists, oxygen from a cylinder can be used.

Adult Resuscitation

In the United Kingdom, the Resuscitation Council has issued guidelines for basic and advanced life support (Figures 12.1 and 12.2). Basic life support (BLS) should be started immediately. Remember to compress the chest to a depth of 5–6 cm at a rate of 100–120/min. Do not stop CPR unless the patient shows signs of regaining vital signs. Around 30% of adult cardiac arrests are secondary to shockable rhythms. Automated external defibrillators (AEDs) are widely available, and defibrillation is now considered part of BLS.

Advanced life support (ALS) secures the airway and supports the circulation using drugs with the aim of restoration or return of spontaneous circulation (ROSC). Tracheal intubation remains the airway of choice. However, adequate oxygenation can be achieved using a supraglottic airway or bag and mask. Intravenous access should be secured or intraosseous access gained if this proves difficult. Chest compression should not be interrupted for more than 5 seconds when attempting defibrillation or tracheal intubation.

Potentially reversible causes of cardiac arrest should be actively sought and treated. These are listed in Figure 12.2 and are known as the ‘4Hs and 4Ts’.

Arrhythmias

Two main types of arrhythmia occur in a cardiac arrest. These are non-shockable and shockable:

- Non-shockable: pulseless electrical activity (PEA) – a QRS complex without a palpable pulse and asystole
- Shockable: ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT)

Within the operating theatre, over 80% of cardiac arrests are non-shockable. Adrenaline (epinephrine) increases the chance of ROSC although there is no evidence that it improves neurological outcomes. Adrenaline 1 mg is administered immediately for non-shockable rhythms. When treating VF/VT cardiac arrest, 1 mg is given once chest compressions have restarted after the third shock and then every 3–5 minutes. Amiodarone 300 mg is also given after the third shock, followed by a further 150 mg after a total of 5 shocks. Atropine is no longer indicated for asystole but remains indicated for bradyarrhythmias.

The core points of management are shown in Figure 12.2.

Concentrations

Adrenaline (epinephrine) ampoules are available at concentrations of 1 in 1,000 and 1 in 10,000. It is important that the amount of adrenaline present in 1 ml of each concentration is known, so that the correct doses can be given at a cardiac arrest:

- 1 in 1,000 contains 1 mg/ml
- 1 in 10,000 contains 100 mcg/ml



Adult basic life support in community settings

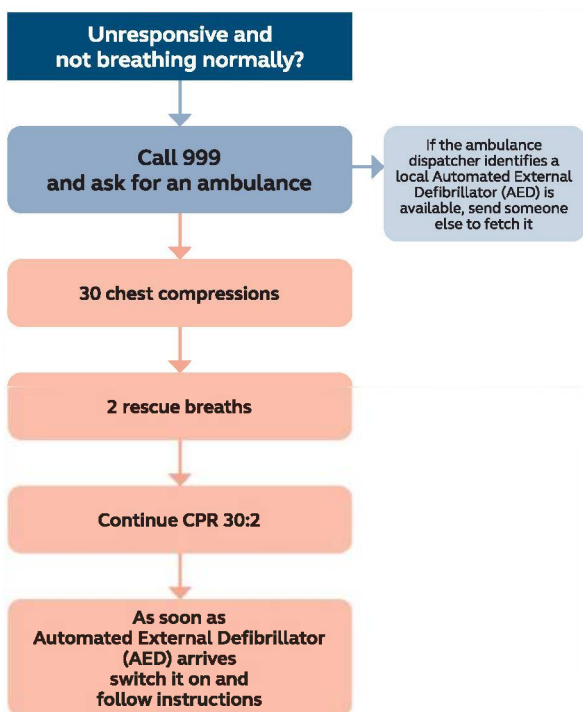


Figure 12.1 Adult basic life support algorithm. Reproduced with the kind permission of the Resuscitation Council (United Kingdom).

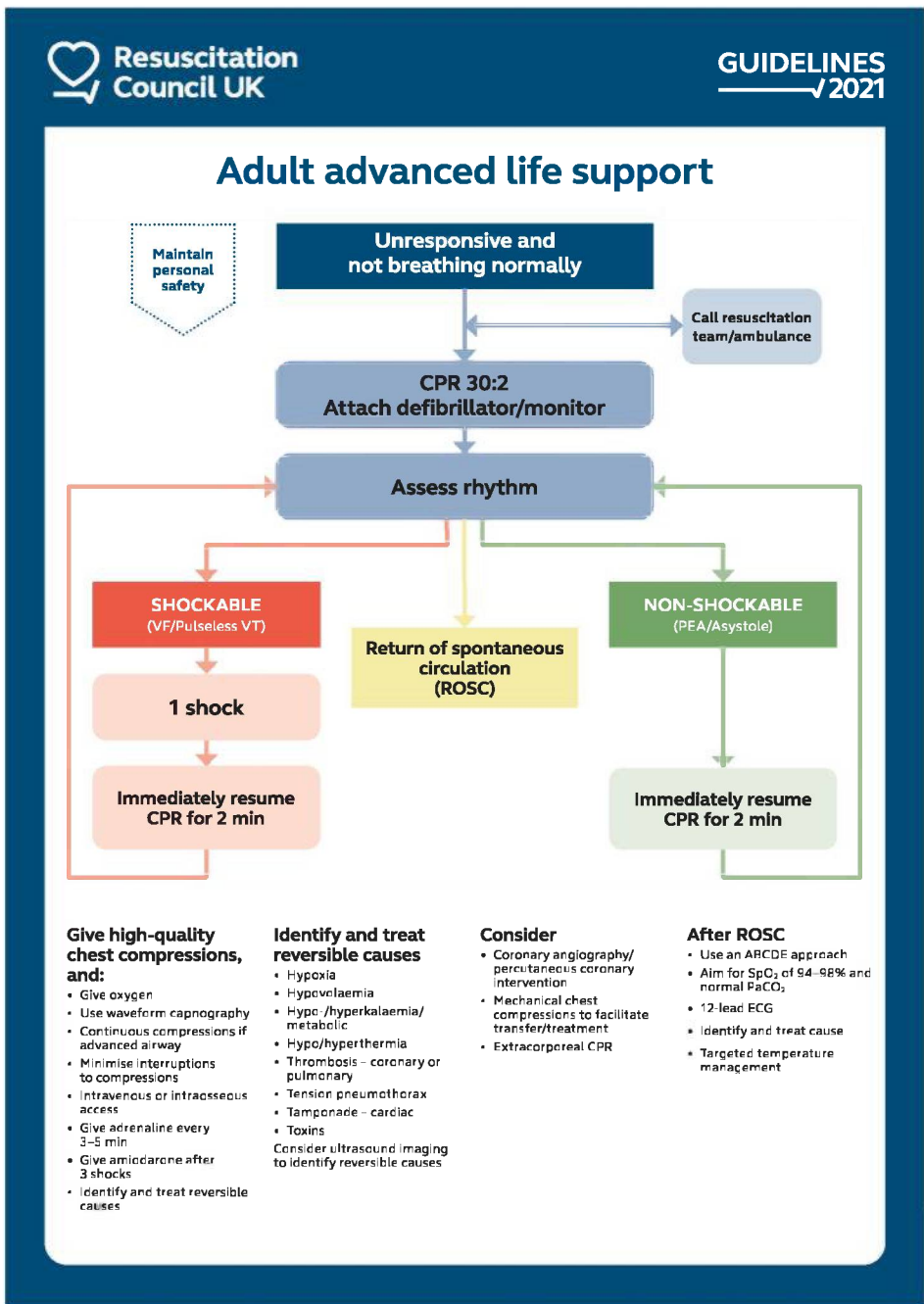


Figure 12.2 Adult advanced life support algorithm. Reproduced with the kind permission of the Resuscitation Council (United Kingdom).

Obstetrics

Fortunately, pregnant patients very rarely suffer from a cardiac arrest. If the woman is less than 25 weeks pregnant, she can be treated as a non-pregnant adult. However, after this there are two main priorities:

1. Cardiopulmonary resuscitation must not occur with the patient in the supine position! After 25 weeks pregnant, the uterus will compress the inferior vena cava resulting in inadequate venous return to the heart. Lateral tilt can be achieved by a physical wedge, or by table tilt and this, together with manual uterine displacement, will reduce this risk.
2. In addition to CPR, above 32 weeks pregnant, caesarean section is indicated. This is because the extent of aortocaval compression makes effective resuscitation almost impossible.

Pregnant patients can be more difficult to intubate than non-pregnant women.

Traumatic Cardiac Arrest

Following trauma, the principles of cardiopulmonary resuscitation remain the same but with emphasis on identifying and treating potentially reversible causes. These are most commonly hypoxia, hypovolaemia, tension pneumothorax and cardiac tamponade. The core points of management are shown in Figure 12.3.

Paediatric Resuscitation

The algorithms for basic and advanced paediatric life support are shown in Figures 12.4 and 12.5. These refer to children under the age of 18 years. Hypoxia is the commonest cause of paediatric cardiac arrests. Hence management algorithms emphasise airway management and oxygenation. Rescue breaths should be given before chest compressions are commenced. Choking is more common than in adults. The choking algorithm is shown in Figure 12.6.

As in adults, high quality chest compressions with minimal interruptions are important and any reversible causes should be identified and treated. The important features are:

- Five initial rescue breaths
- 15 chest compressions: 2 breaths
- Compress the lower half of the sternum, sufficient to depress it by one third of the anteroposterior chest diameter, and a rate of 100–120/min.

Conclusion

The success rate of resuscitation in hospital, as assessed by the number of patients returning home, remains disappointing. The prompt recognition and management of the arrest is essential and, if it occurs during anaesthesia, the cause must be identified and treated.

The rapid establishment of ventilation of the lungs with oxygen and vascular access is essential for successful resuscitation.

Your anaesthetic skills often make you the natural leader of the arrest team.

TRAUMATIC CARDIAC ARREST/ PERI-ARREST ALGORITHM

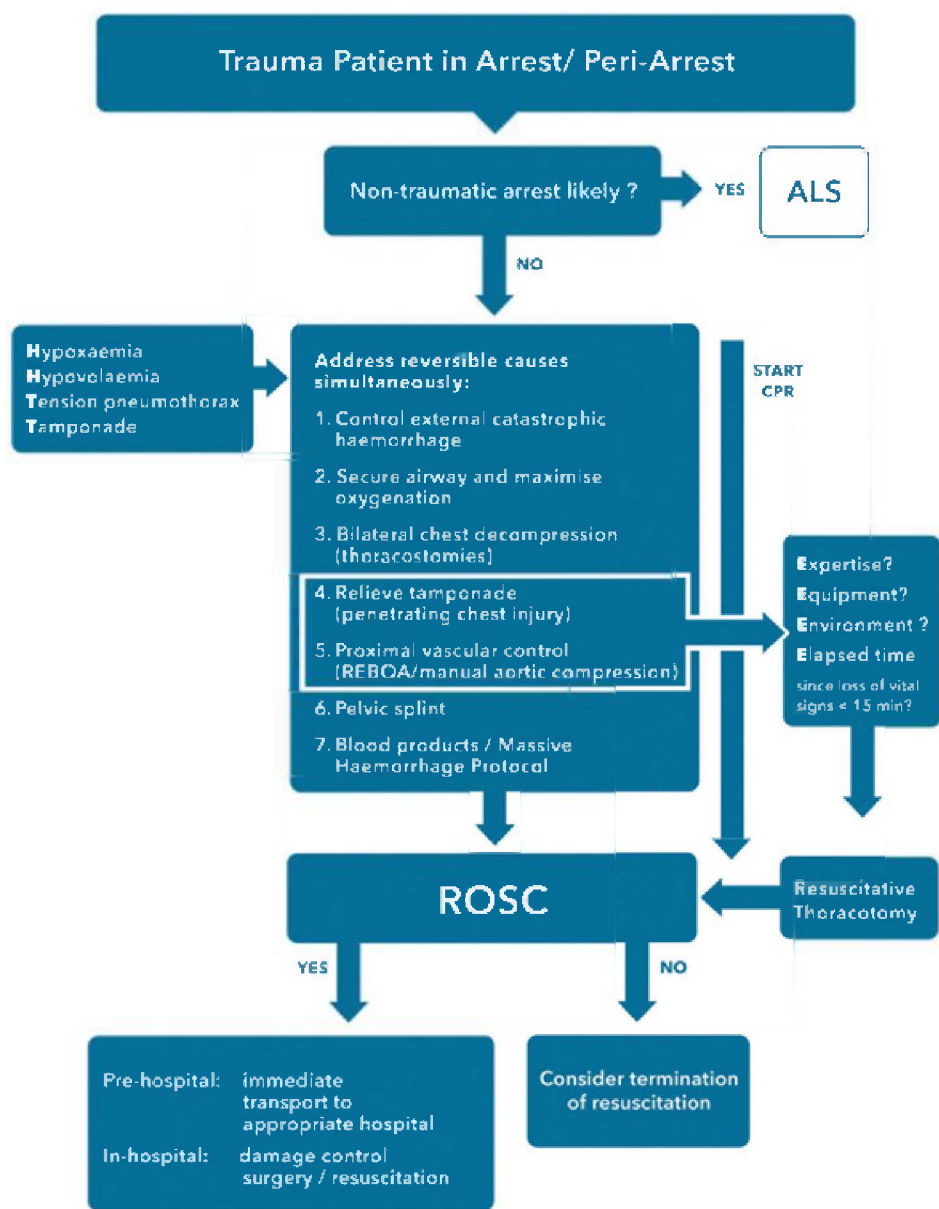


Figure 12.3 Management of traumatic cardiac arrest algorithm.
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Paediatric basic life support

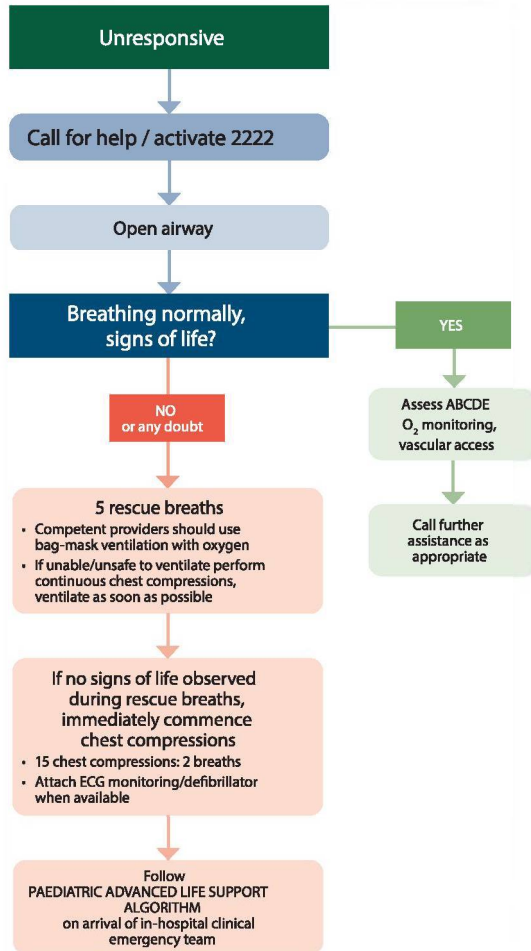


Figure 12.4 Paediatric basic life support (healthcare professionals with a duty to respond). Reproduced with the kind permission of the Resuscitation Council (United Kingdom).

Paediatric advanced life support

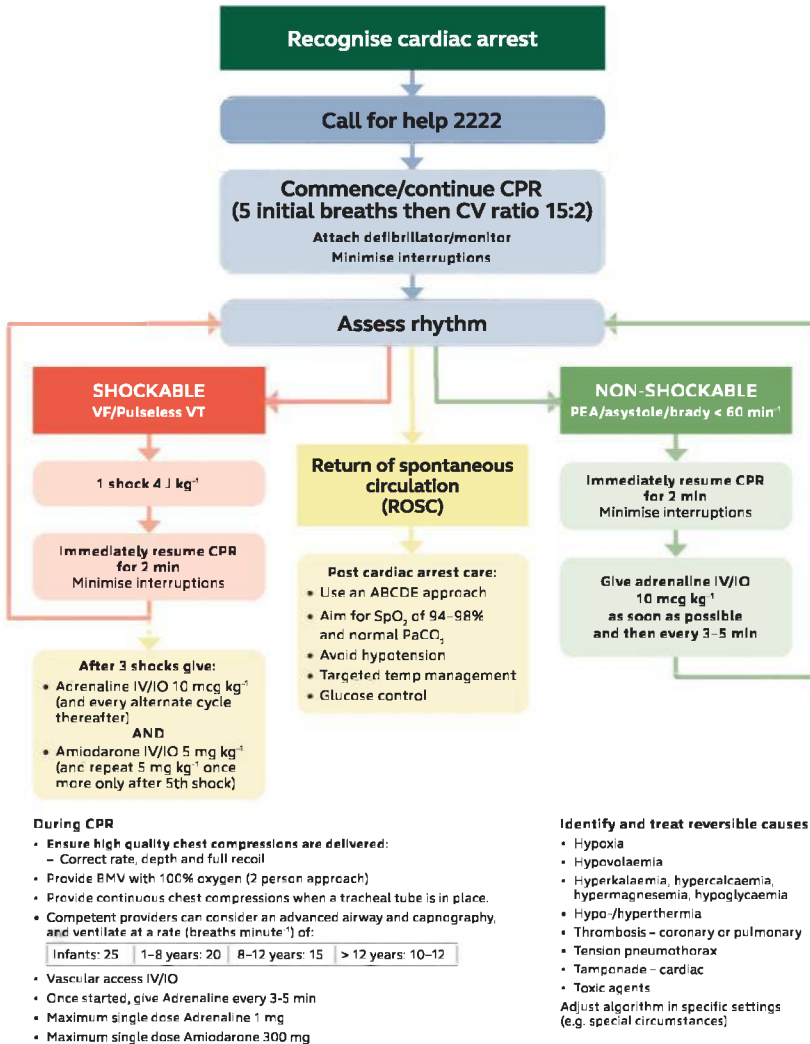


Figure 12.5 Paediatric advanced life support. Reproduced with the kind permission of the Resuscitation Council (United Kingdom).

Paediatric foreign body airway obstruction

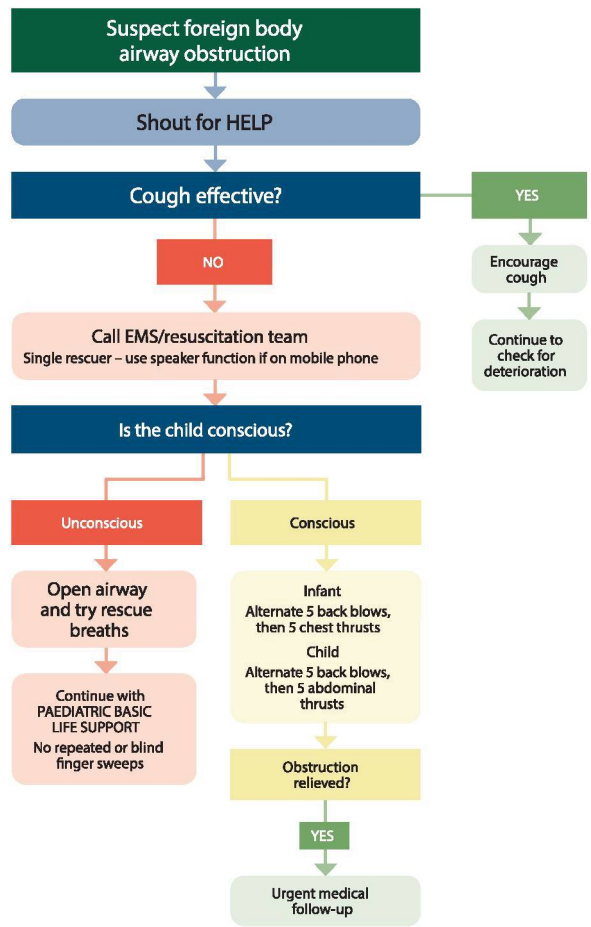


Figure 12.6 Paediatric choking algorithm. Reproduced with the kind permission of the Resuscitation Council (United Kingdom).

Haemorrhage and Blood Transfusion

As an anaesthetist you will be involved in the care of patients who have lost blood, not only from surgery, but in other areas of the hospital such as obstetrics, and following trauma and gastrointestinal haemorrhage. Patients need to be resuscitated to preserve not only blood pressure but also cardiac output and oxygen delivery (see Chapters 10 and 24) to the vital organs. In order to manage these patients optimally you need to consider

What is their circulating blood volume?

How much blood has been lost?

When do I transfuse?

Is this a major haemorrhage?

Circulating blood volume

Blood volume varies with age as shown in Box 13.1.

This is an important calculation to make prior to all patients undergoing major surgery.

Estimation of Blood Loss

This is a difficult area. Surgeons often underestimate blood loss. Moreover, not all blood loss is revealed, such as patients with polytrauma (who may bleed around fractures, into the chest abdomen or pelvis) or with patients bleeding silently out of the surgeon's direct view (such as in minimal access surgery), or simply dripping out of a large wound onto drapes and the floor

During surgery, blood loss can be estimated by various techniques. See Box 13.2.

Swab weighing relies on the principle that 1 ml of blood weighs approximately 1 g. A 3 × 4-inch swab weighs 20 g when dry and about 35 g when saturated. This 15 g difference represents about 15 ml of blood. An 18 × 18 inch swab contains about 150 ml of blood when saturated. Three of these large swabs full of blood contain about 450 ml, which is equivalent to one unit of blood.

Box 13.1 Blood volume formulae

- | | |
|--------------------------|------------|
| • Neonate | • 90 ml/kg |
| • Infants 2 years of age | • 80 ml/kg |
| • Adult male | • 70 ml/kg |
| • Adult female | • 60 ml/kg |

Box 13.2 Blood loss estimation

- Clinical observation
- Weighing of swabs
- Volume of suction
- Dilution techniques

The volume of fluid in the suction apparatus may contain surgical 'washing fluid' as well as blood. This overestimate is a useful precaution, as the amount of blood on the surgical drapes, down the surgeons and on the floor cannot be measured. In major surgery it can easily be equivalent to 1–2 units of blood.

Dilution techniques are rarely used in clinical practice but rely on the measurement of the concentration of haemoglobin in the suction fluid to calculate the blood loss.

However, patients should receive intravenous fluids and a blood transfusion according to cardiovascular variables and measured haemoglobin, rather than relying on the estimates of blood loss. The heart rate, arterial pressure and central venous pressure are obvious guides, as are flow measurements such as stroke volume.

Transfusion Trigger

Blood is administered according to the clinical situation including the progress of surgery and the condition of the patient, especially their comorbidities. For a 70 kg patient, blood loss of less than 10% of total blood volume (i.e., 500 mls) is usually well tolerated and blood loss of >30% (i.e., 1,500 mls) invariably requires transfusion. In between these ranges, clinical judgement determines if and when to transfuse. A haemoglobin concentration of 100 g/l, or a haematocrit of 30%, has been used as a threshold for transfusion but many anaesthetists would, in fitter patients, accept a haemoglobin concentration of 70–80 g/l. Whilst these lower values have been proposed, but there is little physiological reserve if further rapid blood loss occurs.

Major Haemorrhage

This has a number of definitions including loss of more than one circulating blood volume within 24 hours, loss of 50% of total blood volume in <3 hours, bleeding in excess of 150 ml/min⁻¹, or total blood loss in excess of 1.5 L. All hospitals have a major haemorrhage protocol which, when declared, has a hospital-wide response for clinicians, blood banks and others to facilitate a rapid coordinated response to the situation.

You must be familiar with this process and how and when to activate it. Remember to inform the relevant staff when there is no assistance required.

Reducing the Need for Transfusion

A number of strategies are used to reduce the need for transfusion. These include reversing pre-existing coagulopathy where possible, the use of intravenous iron to treat iron deficiency anaemia preoperatively (so patients come to theatre without anaemia), the intraoperative use of tranexamic acid (which is widely used in many surgeries) and cell salvage. There is an ongoing debate as to the role of cell salvage for patients undergoing cancer surgery as to whether or not it might cause seeding of cancer cells.

Blood and Blood Products

Storage

Blood after donation is immediately cooled to 4–6°C. These temperature limits must be rigidly observed to preserve the red cells and minimise the multiplication of chance bacterial contaminants. Blood from the refrigerator should be used within 30 minutes.

A unit (500 ml) of blood is collected into a bag that contains 70 ml of citrate, phosphate and dextrose (CPD) solution. The plasma is commonly centrifuged off for other use. The red cells are then suspended in a saline, adenine, glucose and mannitol (SAG-M) solution. The purpose of the storage additives is shown in Box 13.3.

Whole blood is devoid of functioning platelets after 2–3 days of storage and the clotting factors V and VIII are reduced to 10% of normal within 24 hours. Although adequate amounts of the coagulation factors I, II, VII, IX, X, XI, XII are present in whole blood, red cell concentrates contain virtually no coagulation factors.

Potassium concentrations rise progressively in stored blood and can reach up to 30 mmol/l after 3 weeks. Following transfusion, viable red cells re-establish their ionic pumping mechanism and intracellular uptake of potassium occurs rapidly. Blood that is 2–3 weeks old is acidic, with pH values down to 6.6, resulting mainly from the lactic acid generated by red cell metabolism.

Preparations

There are about 20 different types of blood and blood products available for adult and paediatric use. The main ones used by anaesthetists are shown in Table 13.1.

Box 13.3 Additives used in red cell storage

- Citrate: chelates calcium
- Phosphate: maintains ATP, reduces haemolysis and increases red cell survival
- Saline: decreases viscosity of red cell concentrates
- Adenine: maintains ATP, improves red cell mobility
- Glucose: energy for red cells, decreases hydrolysis of ATP
- Mannitol: reduces haemolysis

Table 13.1 Blood products in common use

Blood/blood product	Volume (ml) per unit	Storage temperature (°C)	Shelf life
Whole blood	500	4–6	35 days
Red cell concentrates	300	4–6	35 days
Fresh frozen plasma	150	–30	1 year
Platelet concentrates	50	22	5 days
Cryoprecipitate	18	–30	1 year

Fresh frozen plasma (FFP) contains all the components of the coagulation, fibrinolytic and complement systems. In addition, it also has proteins that maintain oncotic pressure, fats and carbohydrates.

Cryoprecipitate contains factor VIII and fibrinogen.

Prothrombin complex concentrate (e.g., Beriplex) is used for the emergency correction of oral anticoagulation with warfarin. It increases factors II, VII, IX, X and the anticoagulant inhibitors protein C and protein S.

Complications of Blood Transfusion

Complications of blood transfusion include those listed in Box 13.4.

Physical

Circulatory overload should be avoided by the judicious transfusion of blood according to the measured cardiovascular variables such as arterial pressure, central venous pressure and heart rate. Air embolism can occur from errors in blood administration, particularly when the bags are pressurised.

Anaesthetised patients have impaired temperature regulation, and the rapid transfusion of cold blood exacerbates any hypothermia present. The value of warming blood during transfusion has been demonstrated repeatedly, and this should be undertaken on every occasion.

Box 13.4 Blood transfusion complications

- Physical
 - fever
 - transfusion related circulatory overload (TACO)
 - embolism (air, microaggregates)
 - hypothermia
 - transfusion related lung injury (TRALI)
- Immunological
 - Haemolysis (acute and delayed)
 - type I hypersensitivity
 - graft versus host reactions
 - Transfusion related immunomodulation (TRIM)
- Biochemical
 - acid–base disturbances
 - hyperkalaemia, hypocalcaemia
 - citrate toxicity
- Infective viral (e.g., HIV, hepatitis), bacteria, protozoan (e.g., malaria), prion (CJD)
- Disseminated intravascular coagulation
- Human error: wrong blood transfused/wrong name on bottle, and so on

Immunological

Pyrogenic reactions can occur in the recipient to white cell antigens or the polysaccharide products of bacterial metabolism. Rarely, stored blood contains gram-negative bacteria. Plasma proteins are responsible for any anaphylactic or allergic reactions that happen. These reactions are rare, and range from severe hypotension to mild rashes. 'Graft versus host' reactions are caused by blood containing HLA-incompatible, immunocompetent lymphocytes being given to patients with immunosuppression. Pyrexia may develop, and the disease can be fatal without suitable transfusion precautions. The use of leucocyte-depleted red cell concentrates is expected to decrease the incidence of immunological complications.

It has been suggested, but is unproven, that patients with malignancy requiring transfusion have a greater risk of a recurrence, perhaps related to transfusion related immunomodulation (TRIM) on cancer cell surveillance.

Biochemical

The rapid infusion of large volumes of stored blood may result in acidosis in the recipient. This is particularly likely to occur if the liver is unable to metabolise the lactate and citrate because of inadequate hepatic perfusion, hypothermia or even hepatic disease. A persistent acidosis decreases myocardial function. A temporary improvement in cardiac output often follows the use of intravenous calcium chloride in these circumstances, although there is no obvious relationship to plasma ionised calcium values. The restoration of normal liver function usually corrects the problem.

Depletion of 2,3-diphosphoglycerate (DPG) in the red cells shifts the oxygen dissociation curve to the left and oxygen is released less easily from transfused blood. Modern additives have improved the concentration of 2,3-DPG for up to 14 days, and 25% of cells are back to normal function in 3 hours and 50% in 24 hours after transfusion.

Infective

All blood products except albumin and gamma globulin can transmit infectious diseases. Hepatitis B, C, E, syphilis and HIV are screened for, but cytomegalovirus, malaria, Epstein-Barr virus and parvovirus infection can be transmitted following transfusion.

Haemolytic Transfusion Reactions

Haemolytic and pyrogenic reactions are usually due to errors in the clerical administration of blood. However, blood group and rhesus incompatibility can also result in severe haemolytic reactions. Blood should be checked by two people against the patient's identity band. The recipient's name, hospital number, blood group and blood expiry date must be checked and signed for. In practice, during emergency work, it is often not possible for two people to check the blood and it is then imperative that you slowly and deliberately check each unit. Sometimes you have the opportunity to check all the blood before inducing anaesthesia.

Disseminated Intravascular Coagulation

Disseminated intravascular coagulation (DIC) is widespread activation of the coagulation and fibrinolytic systems, which results in clotting throughout the whole vasculature. It has many possible causes, but can occur in 30% of cases of massive transfusion. It presents

primarily as a haemorrhagic disorder caused by loss of platelets and soluble clotting factors (especially fibrinogen).

Massive Blood Transfusion

Various definitions exist for this term. It is normally defined in one of three ways, based on volume and speed of replacement:

- acute administration of more than 1.5 times the estimated blood volume
- replacement of the patient's total blood volume by stored bank blood in less than 24 hours
- acute administration of more than 50% of the blood volume per hour

There is an increasing trend towards replacing all blood components at an early stage. This means that for every two units of red cells, consideration should be given to replacement with a pack of FFP and a pool of platelets. The aim is to prevent a coagulopathy rather than having to treat it.

It is recommended that, after a four-unit transfusion, a set of basic screening tests is undertaken to exclude DIC. These are:

- haemoglobin and platelet count
- prothrombin time (PT) and activated partial thromboplastin time (APTT)
- plasma fibrinogen concentration
- fibrin degradation products
- pH from arterial blood gas analysis
- point of care testing, e.g., thromboelastography (see below)

The diagnosis of DIC is made by noting the trend:

- increase: APTT, PT, fibrin degradation products
- decrease: platelet count, fibrinogen concentration

The correction of these abnormalities is made after haematological consultation.

The abnormalities in PT and APTT are normally corrected by the administration of FFP (four units). A low platelet count should be restored to above $100 \times 10^9/l$ by the administration of 6–8 units of platelets. Low fibrinogen levels are treated with cryoprecipitate, aiming for a level of more than 1 g/l (normal 2–4.5 g/l). Recombinant activated factor VIIa can also be administered, if bleeding continues in spite of the use of FFP, platelets and cryoprecipitate. Tranexamic acid, an anti-fibrinolytic, is increasingly used in major haemorrhage.

In addition to laboratory tests to measure clotting, as shown above, point of care tests are also available. A thromboelastography is a whole blood viscoelastic test such as (TEG® or ROTEM®). They provides quick (often 20–30 minute response) guidance on the state of the complete clotting process. Many theatres or ICUs have this device which assess not only clotting factors (analogous to PTT and APTT), but also information on clot formation and clot strength, platelet activation and fibrinolysis. This detailed information can be used to provided targeted blood products.

The Practicalities of Blood Transfusion

Ensure that you are well prepared. Patients undergoing surgery should either have blood cross-matched or have a group and save sample. If the patient is not known to blood bank

then they will require two samples, which is designed to improve patient safety. You may have to take the second sample yourself. For many patients, especially those without antibodies, electronic issue can be used which is rapid and does not require formal crossmatching but matches the data from the automated analyser (i.e., blood group and antibody status of the patient) with the details on the blood unit. In cases of extreme urgency un-crossmatched O negative or group-specific blood can be used but should be rarely required.

The patient will need a large cannula (preferably 16 G), a blood administration set which contains a 170 micron screen filter. You must not use the standard administration set for crystalloids. There should be a fluid warming device attached too.

Ensure that you have the correct patient, confirmed by their date of birth and hospital ID number. Ensure that the blood to be transfused is compatible with the patient. There are several checks to stop incompatible blood being given to patients (Box 13.5). Do them carefully. Transfusion of the wrong blood is classified as a never event and can be fatal. Remember too, if you are personally taking blood from a patient ensure that the details are correct and to label the bottle immediately yourself.

Blood Transfusion Refusal

Some patients refuse blood for a variety of reasons, including religious beliefs (e.g., Jehovah's Witness). Patients may vary in their choice and many will accept derivatives of primary blood components such as clotting factors human albumin solution and intraoperative cell salvage. This must be identified prior to surgery and the appropriate paperwork must be signed (many patients carry a card which is an advance directive). This absolves clinicians from the consequences of not giving blood.

Box 13.5 Blood transfusion checks

- Blood product
 - check against label and compatibility and traceability tag
- Patient details
 - ensure identification details are the same on identity band, notes, compatibility and traceability tag
 - hospital number, first name, last name, date of birth, gender
 - IN GENERAL ANAESTHESIA CONFIRM ALL THESE CAREFULLY: THE PATIENT IS UNCONSCIOUS AND FATAL MISMATCH ERRORS CAN OCCUR
- Blood group
 - ensure ABO and Rh D group and donation number are the same on blood label and compatibility and traceability tag
- Special requirements
 - gamma radiation or CMV-seronegative
- Expiry date is the same on all labels and tags
- Inspect blood before use
 - leaks, evidence of haemolysis, discolouration or clots

In the case of children and transfusion refusal, where medical staff feel that transfusion is absolutely essential and in the best interests of a child, it may sometimes be necessary to ask a judge's permission (if time allows) or to give blood to the child without the parents' permission, in the case of an emergency.

Conclusion

Surgery results in blood loss. You must know how to estimate this loss, understand the blood products available and be able to use cardiovascular and haematological monitoring to transfuse them appropriately.

Think of blood as another potent drug that you will give frequently. It must be checked carefully before use, it can be life-saving, but it also has unwanted side effects. You must attend blood transfusion training when offered at your hospital.

If you are taking a sample yourself for crossmatching, ensure you have the correct identity of the patient. Label the blood bottle and perform the paperwork immediately yourself once you have taken the blood.

The greatest disaster is to give the wrong blood to the patient. It is imperative that the blood is checked against the patient's identity band. Never check the blood bags solely with the transfusion form. Finally, remember blood transfusion is expensive and not risk-free. Sometimes a single unit will suffice.

Anaphylactic Reactions

Although minor allergic reactions are not uncommon in anaesthesia, major anaphylactic reactions are rare. Prompt treatment, with the emphasis on the early use of adrenaline (epinephrine), will usually lead to a successful outcome.

Anaphylaxis is a severe, life-threatening, generalised or systemic hypersensitivity reaction. The allergen crosslinks two IgE receptors on sensitised mast cells and basophils, causing release of histamine, serotonin and other vasoactive substances. An anaphylactoid or non-allergic reaction results in the same clinical manifestations as an anaphylactic reaction, but is not mediated by a sensitising IgE antibody. Previous exposure to a drug will not have occurred, but susceptible individuals often have a history of allergies.

Every anaesthetist should know and practise an 'anaphylaxis drill'. The incidence of anaphylaxis is about 1 in 10,000 anaesthetics. It occurs more commonly in women than in men. The causes of anaphylaxis occurring during anaesthesia are listed in Table 14.1. Antibiotics are the major cause of anaphylactic reactions, and it has been suggested that they should always be given before induction of anaesthesia, although this is often impractical.

Many other agents less frequently cause anaphylaxis (including propofol, opioids, local anaesthetics and latex). There is no evidence to support the treatment of rocuronium anaphylaxis with sugammadex.

The clinical manifestations of severe allergic reactions are shown in Box 14.1. Note that not all signs are present. For example, cardiovascular collapse (or even cardiac arrest) may be the only sign, with no bronchospasm, and so on. In particular, skin signs need adequate perfusion and may be absent until this has been restored.

A grading system has been developed to quantify the extent of the reaction, as seen in Table 14.2.

Table 14.1 Causes of anaphylaxis

Drug type	Percentage of cases	Comments/examples
Antibiotics	47	Teicoplanin and co-amoxiclav
Neuromuscular blocking drugs	33	All (especially suxamethonium)
Chlorhexidine	9	E.g., impregnated central lines
Patent blue dye	5	Used for breast/melanoma surgery

Box 14.1 Signs of severe allergic drug reactions

- Hypotension (accompanied by tachycardia or bradycardia)
- Pruritus, flushing, erythema
- Coughing on induction of anaesthesia
- Angioedema
- Laryngeal oedema with stridor
- Bronchospasm
- Disseminated intravascular coagulation
- Sudden death

Table 14.2 Grading of anaphylaxis

Grade	Clinical signs
1	Skin/mucosal signs, urticaria, angioedema
2	Multi organ involvement eg hypotension, bronchospasm
3	Life threatening organ involvement severe hypotension, cardiac arrhythmias, severe bronchospasm
4	Cardiac arrest

Management

The management of an anaphylactic reaction should be considered in two stages:

- immediate management
- secondary management

Immediate Management (Box 14.2)

A reduction in peripheral vascular resistance and a marked loss of intravascular volume (up to $\frac{3}{4}$ in the first 15 minutes) are the initial pathophysiological changes. Fluid therapy is important for resuscitation, and central venous pressure measurement may be necessary. However, the priority is intravenous adrenaline, but remember it has a short duration of action and will need to be repeated or given by infusion

Secondary Management (Box 14.3)

Intensive care facilities may be needed. Awareness can occur and should be prevented by ensuring adequate depth of anaesthesia.

Investigations

After a severe allergic drug reaction, the patient must be investigated thoroughly and both the patient and the general practitioner informed of the results. This is usually carried out in

Box 14.2 Anaphylaxis – immediate management

- Use ABC approach and work as a team
- Stop administration of suspected drug, if possible
- Call for help and note time
- Stop anaesthesia and surgery, if feasible. Unconsciousness can be maintained with inhalational agent
- Maintain airway
- Give 100 per cent oxygen (consider intubation and ventilation)
- Give intravenous *adrenaline* (especially if bronchospasm present):
 - 0.5–1.0 ml of 1:10,000 (50–100 mcg)
 - 5–8 mcg/min if prolonged therapy required children 1.0 mcg/kg
- Repeat bolus of adrenaline as necessary
- Start intravascular volume replacement by crystalloid 10–20 ml/kg
- Consider early CPR with hypotension (MAP < 50 mmHg)
- Transfer patient to appropriate critical care area

Box 14.3 Anaphylaxis – secondary management

- Adrenaline-resistant bronchospasm. Consider:
 - intravenous salbutamol 250 µg loading dose and 5–20 µg/min maintenance, or
 - aminophylline 4–8 mg/kg over 20 minutes
- Bronchospasm and/or cardiovascular collapse. Consider:
 - intravenous hydrocortisone 200 mg, or
 - methyl prednisolone 2 g
- Antihistamines. Consider:
 - intravenous chlorpheniramine 10 mg diluted, administer slowly
- After 20 minutes and severe acidosis present. Consider:
 - sodium bicarbonate (25–50 ml 8.4 per cent)
- Catecholamine infusions. Consider:
 - adrenaline 5 mg in 500 ml (10 µg/ml) at rate 10–85 ml/h, or
 - noradrenaline 4 mg in 500 ml (8 µg/ml) at rate 25–100 ml/h
 - Other agents include metaraminol and glucagon
- Consider coagulopathy: clotting screen
- Arterial gas analysis for oxygenation and degree of acidosis
- Do not extubate until airway safe

consultation with a clinical immunologist. The investigations normally take place in the following order:

- 1 blood tests for confirmation of allergic reaction
- 2 full anaesthetic history
- 3 skin tests
- 4 patient reporting: hazard card, MedicAlert bracelet

At the time of the reaction, and 1, 2 and 24 hours later, serial blood samples (5–10 ml clotted blood) are taken for tryptase (a neutral protease released from mast cells). Some countries advocate histamine measure although it has a short half-life of 15–20 minutes.

These will confirm that a reaction has occurred, but will not identify the causative agent. Ensure that you liaise with the hospital laboratory staff: the samples are precious.

After a full medical history and a delay of at least four weeks, a 'skin prick test' is undertaken. This correctly identifies most causative agents. Full resuscitation equipment must be available, and detailed protocols have been described, indicating appropriate dilutions of drugs and the use of control solutions.

The case must be reported to the Medicines and Healthcare Products Regulatory Agency (MHRA) in the United Kingdom via the 'yellow card' system. The patient should carry a written record of the reaction and either an anaesthetic hazard card or a MedicAlert bracelet.

Conclusion

Life-threatening anaphylaxis is a rare complication of anaesthesia. A knowledge of the immediate and secondary management must be learnt during the early months of training.

The mainstay of immediate treatment is intravenous adrenaline. Remember:

ANAPHYLAXIS = ADRENALINE (EPINEPHRINE).

Malignant Hyperthermia

Malignant hyperthermia (MH) is a rare, pharmacogenetic complication of general anaesthesia that results from an abnormal increase in muscle metabolism in response to all potent inhalational agents and suxamethonium. There is often a family history of death or major problems associated with anaesthesia, and the gene is inherited as an autosomal dominant. Even with the ready availability of a specific therapeutic drug, dantrolene, deaths from MH still occur, mostly because of a failure to recognise the onset of the syndrome. If you are lucky, you will never see a patient with MH, but we know an anaesthetist who induced MH in three patients within five years! The main reason why this rare syndrome provokes so much attention is because, like anaphylaxis, it is one of those occasions when an anaesthetic drug can kill the patient.

The primary defect in MH is in calcium homeostasis within the sarcoplasmic reticulum of skeletal muscle. Usually the excitation and contraction (EC) of muscle fibres are tightly coupled but in MH there is dysregulation of this EC coupling, causing abnormal increases in calcium ion concentration on exposure to triggering agents. This results in marked biochemical changes with acidosis, heat production and muscle stiffness.

Estimates of the incidence of MH vary, but a figure of 1 in 100,000 is commonly cited. This value represents typical practice in a district general hospital, but there is an increased incidence in the following groups:

- males
- children and young adults
- patients with congenital musculoskeletal disorders such as myopathies

Thus, if you work in a major orthopaedic centre, which undertakes scoliosis surgery in adolescents, you are more likely to encounter the problem.

It is helpful to try to identify MH before surgery by noting the following points:

- family history of problems or sudden death associated with general anaesthesia
- in vitro contracture testing (IVCT) of muscle biopsy to caffeine and halothane
- genetic testing

In vitro testing of a muscle biopsy is, at present, the most accurate method of diagnosing MH, but it is undertaken only in specialised centres (Leeds in the UK). If a child requires testing they must be >10 years of age and >30 kg in weight. The patient is described as MHS (susceptible), MHN (normal) or MHE (equivocal). MHE means that they respond positively to either halothane or caffeine, but not both.

MH is triggered by all volatile anaesthetic drugs and suxamethonium. The response to the administration of suxamethonium at induction of anaesthesia is abnormal in some MH-susceptible patients. Instead of the usual fasciculations followed by muscle relaxation, there are vigorous fasciculations with failure to relax and, in particular, masseter spasm. This

spasm makes opening the mouth difficult, and so tracheal intubation may be a problem. The occurrence of masseter spasm should be treated as an important prognostic indicator of possible MH susceptibility (approximately 50%).

Management is undertaken as shown below:

- 1 Call for help
- 2 Halt anaesthesia
- 3 Do not give volatile agents
- 4 Elective surgery: abandon and monitor patient
- 5 Emergency surgery:
 - follow advice
 - monitor patient
 - use 'safe' techniques (see Box 15.4)
 - prepare to treat MH
 - perform arterial gas analysis early and regularly
 - The key feature is not to administer potent volatile agents.

Suxamethonium alone usually results in a relatively mild, self-limiting MH, whereas the combination of suxamethonium with a volatile anaesthetic is a potent trigger.

Presentation

There are no obvious signs of the onset of MH, other than an abnormal response to suxamethonium. The main clinical signs are shown in Box 15.1.

The peripheral circulation is often decreased in MH, due to the marked increase in catecholamine secretion, so do not wait for the brow to feel hot – it may never happen! The metabolic signs of MH are more obvious, and reflect the massive stimulation of muscle metabolism (Box 15.2).

The earliest objective sign of the onset of MH is increased CO₂ production as shown by a raised end-tidal CO₂ concentration with capnography. Body temperature is not a reliable sign, unless a good estimate of core temperature is available (not rectal). The metabolic changes provide the basis for the confirmation of the suspected diagnosis. Arterial gas analysis should be undertaken, and in established MH it will show a severe acidosis, both respiratory and metabolic, and often hyperkalaemia.

Once the diagnosis of MH has been confirmed, then correct treatment must be started immediately.

Box 15.1 Clinical signs of malignant hyperthermia (MH)

- Abnormal response to suxamethonium (masseter spasm)
- Tachycardia (possibly arrhythmias)
- Tachypnoea
- Increased use of soda-lime
- Peripheral cyanosis
- Muscle stiffness
- Patient feels hot

Box 15.2 Metabolic signs of malignant hyperthermia

- Acidosis
 - increased CO₂ production
 - increased lactic acid production
- Hyperkalaemia
- Haemoconcentration
- Hyperglycaemia
- Hypoxaemia
- Hyperthermia

Box 15.3 Overall management plan for malignant hyperthermia

- Specific treatment dantrolene
- General supportive therapy
 - acidosis
 - hyperkalaemia
 - haemoconcentration
 - arrhythmias
 - hyperthermia

Treatment

The treatment of MH can be considered as specific therapy with dantrolene and general supportive management (Box 15.3).

Dantrolene must be administered promptly. The following guidelines have been found to be effective:

1. Discontinue volatile agents and terminate surgery, if possible. Stop all warming devices.
2. Hyperventilate with 100% O₂ (2–3 times minute volume). Use total intravenous anaesthesia to maintain unconsciousness
3. Correct metabolic acidosis (at least 100 mmol bicarbonate).
4. Dantrolene 2–3 mg/kg intravenously and repeated every 5 minutes until MH controlled and treatment goals are reached – an ET CO₂ of > 6KPa on normal minute ventilation and a core temperature of < 38.5°C. Assess therapy by repeat checks of:
 - arterial blood gas analysis, CK levels, glucose, clotting (e.g., DIC), renal and liver function
 - tachycardia
 - muscle stiffness
 - temperature

Box 15.4 Anaesthesia in suspected malignant hyperthermia

- Regional anaesthesia where possible
- General anaesthesia
 - anaesthetic machine: carefully prepared
 - premedication: benzodiazepine, opioids
 - induction: all intravenous drugs safe
 - neuromuscular blockade: all non-depolarising drugs safe
 - maintenance: N₂O–O₂ – total intravenous anaesthesia

5. Establish appropriate lines/monitoring, including arterial and central lines and urinary catheter
6. Correct hyperkalaemia (insulin with dextrose, calcium chloride or haemofiltration)
7. Rehydrate
8. Treat severe tachycardia (small dose of beta-blocker)
9. Cool if necessary (infants and children only)
10. Induce diuresis when rehydrated as kidney injury is common due to free myoglobin
11. Monitor carefully for 24 hours (ICU)

Dantrolene is difficult to dissolve and it can take a long time to form a solution, with patients needing multiple vials. One person should be assigned this role. Once it is in suspension, use it. Fortunately, dantrolene works rapidly, and the initial dose is often sufficient to stop the hypermetabolism within a few minutes.

Do not waste time on cooling the patient unless it is an infant or child; thermogenesis will cease once the MH is controlled.

Anaesthesia for MH-Susceptible Patients

It is much easier to manage MH if you are aware of the problem before the anaesthetic. A 'safe' technique means avoiding the potent volatile agents and suxamethonium and using a 'clean' anaesthetic machine. This is obtained by removing the vaporisers, changing all disposable tubing and then purging the machine with 10 l of O₂ for 10 minutes. Some hospitals have activated charcoal filters which also rapidly reduce the volatile concentration in the circuit. Regional or general anaesthesia may be used (Box 15.4).

Full monitoring must be undertaken – capnography, oxygen consumption, temperature measurement and often the intravascular measurement of arterial pressure and central venous pressure. The patient can be safely recovered in a PACU which has very low levels of volatile anaesthetics.

Conclusion

Malignant hyperthermia is not easy to diagnose. Although it is rare, the possibility of MH must be considered if you find an unexpected increase in CO₂ excretion, tachycardia or tachypnoea during anaesthesia. The diagnosis is further suggested by arterial gas analysis.

Dantrolene is effective if given early. Know where it is kept in theatre – one day you may need it urgently.

Local Anaesthetic Systemic Toxicity

Local anaesthetic agents are used to provide intra- and postoperative analgesia. Intraoperatively they can be used as the sole analgesic for surgery, but they are commonly used with sedation or in combination with general anaesthesia. You must always be aware of the potential for local anaesthetic systemic toxicity (LAST).

Lidocaine, bupivacaine and L-bupivacaine are the most popular local anaesthetic drugs. Others such as ropivacaine and prilocaine are also available. The choice of drug depends on the speed of onset, the total amount of drug needed and the duration of action required. The characteristics of the commonly used drugs are shown in Table 16.1.

Adrenaline (epinephrine) is sometimes added to the local anaesthetic agent to prolong its use, and to decrease the vascularity of the operative field (e.g., in thyroid surgery). It must not be used in proximity to terminal arterioles or arteries, as an adequate collateral arterial supply is not available to perfuse distal tissues, and ischaemia will occur. The recommendations for the safe use of adrenaline are listed in Box 16.1.

You will encounter both racemic bupivacaine (i.e., S- and R-enantiomers) as well as levobupivacaine (comprising only the S-enantiomer). The latter has a far safer cardiovascular and neurological profile as well as having a slight vasoconstrictor action, slowing systemic absorption and slightly prolonging its action.

What Does the Term 'Percentage' Mean?

Local anaesthetic drugs come in vials displaying the percentage concentration contained. The word 'percentage' means grams per 100ml. The maximum dose of local anaesthetic can be calculated as follows. For example, if you are using 1 per cent plain lignocaine in an 80 kg patient: 1 per cent is 1 gram in 100 ml, which is 1000 mg in 100 ml, which is 10 mg in 1 ml

Table 16.1 Characteristics of local anaesthetic drugs

Agent	Duration (h)	Maximum dose	
		Plain (mg/kg)	With adrenaline (mg/kg)
Lignocaine	1–3	3	7
Bupivacaine	1–4	2	2
L-Bupivacaine	2–6	2	2
Ropivacaine	1–6	3	3
Prilocaine	4	6	-

Box 16.1 Recommendations for the safe use of adrenaline in local anaesthetic solutions

- No hypoxia
- No hypercarbia
- Caution with arrhythmogenic volatile agents
- Concentration of $\leq 1:200,000$
- Dose less than 20 ml of 1:200,000 in 10 min
- Total dose less than 30 ml/h

(in the same way that 1 per cent propofol contains 10mg/ml). The maximum dose of plain lignocaine is 3 mg/kg (Table 16.1) so the patient can have a total of $3 \times 80 \text{ mg} = 240 \text{ mg}$. As there are 10 mg/ml the total dose is 24 ml 1 per cent plain lignocaine. Similar calculations can be made for other concentrations.

The maximum dose should not be exceeded when these drugs are used subcutaneously, as toxicity may occur. The administration of local anaesthetics accidentally into veins or arteries will also cause LAST. Toxicity can be mild or severe and should be considered in any patient who has an onset of cardiovascular or neurological signs. More recent changes to practice such as ultrasound guided blocks and the use of NRFit syringes may further reduce the incidence of LAST.

Signs and Symptoms of Mild LAST

The signs of mild toxicity are shown in Box 16.2. A patient with mild toxicity must be observed carefully in case severe toxicity occurs. Stop administering the drug and monitor the patient with an ECG. Mild symptoms usually resolve quickly when drug administration ceases, but severe toxicity can develop.

Signs and Symptoms of Severe LAST

The signs of severe toxicity (Box 16.3) may occur at the time of injection of the local anaesthetic but also up to 20 minutes after the drug has been injected. Surgeons may inadvertently cause toxicity when performing operations under local anaesthesia or when injecting local anaesthetics at the end of surgery. Anaesthetists can cause toxicity from topping up epidural analgesia inappropriately and when performing specific nerve blocks. It is important to remember that the cardiotoxic effects of local anaesthetics, especially bupivacaine, are very hard to reverse and prolonged treatment of a patient with local anaesthetic toxicity is needed.

Treatment of Severe Local Anaesthetic Toxicity

Intravenous lipid emulsion (intralipid) should be stored in the theatres and you should know where it is. The immediate management of toxicity is shown in Boxes 16.4, 16.5 and 16.6.

Success is dependent on a prompt diagnosis and prolonged treatment of the patient. Follow-up includes transfer to a critical care area until recovery has occurred. Tests to exclude iatrogenic pancreatitis should be undertaken for two days.

Box 16.2 Signs of mild LAST

- Anxiety
- Restlessness
- Nausea
- Tinnitus
- Perioral tingling
- Tremor
- Tachypnoea

Box 16.3 Signs of severe LAST

- Sudden alteration in mental state with agitation or loss of consciousness, with or without tonic-clonic convulsions
- Cardiovascular collapse
 - sinus bradycardia
 - conduction blocks
 - ventricular arrhythmias
 - asystole

Box 16.4 Immediate management of severe local anaesthetic toxicity

- Stop injecting the local anaesthetic
- Call for help
- Maintain airway with 100 per cent oxygen
- Anaesthetist may need to intubate trachea to secure the airway
- Intravenous access (should already be in situ)
- Control seizures by diazepam bolus 5 mg, thiopentone, propofol or magnesium 4 g slowly
- Assess cardiovascular status throughout

Box 16.5 Treatment of severe local anaesthetic toxicity without circulatory arrest

- Treat hypotension, bradycardia and arrhythmias conventionally
- Consider intravenous lipid emulsion 20 per cent
 - give bolus of 1.5 ml/kg followed by intravenous infusion at 15 ml/kg/h
 - increase to 30 ml/kg/h after 5 min if cardiovascular or clinical deterioration The initial bolus can also be repeated twice
 - do not exceed a total dose of 12 ml/kg
- Propofol is not a substitute
- Lignocaine should not be given to treat arrhythmias

Box 16.6 Management of cardiac arrest associated with local anaesthetic injection

- Start CPR as per guidelines Manage arrhythmias using the same guidelines; they may be refractory to treatment
- Prolonged resuscitation may be necessary
- Treat with intravenous lipid emulsion 20 per cent
 - a bolus of 1.5 ml/kg over 1 minute. Can be repeated twice at 5-minute intervals, a maximum of 3 doses can be given
- Recovery from cardiac arrest may take 1 hour
- If facilities are available, cardiopulmonary bypass may be needed

Other rarer reactions include anaphylaxis particularly with older ester local anaesthetics (LAs) and prilocaine induced methaemoglobinaemia as a result of its metabolite, o-toluidine. This can be treated with methylene blue.

Conclusion

Local anaesthetic toxicity is rare but can kill! Know the safe doses of drugs, aspirate prior to injection to avoid intravascular administration and give all local anaesthetics slowly. Resuscitation, if severe toxicity occurs, can take several hours.

Stridor: Upper Airway Obstruction

Acute stridor is a life-threatening emergency. Get senior experienced help immediately to manage the patient. It usually occurs in children, but is occasionally found in adults. Complete obstruction of the upper airway may occur rapidly, and the change from partial to complete obstruction is often unpredictable. Upper airway obstruction will lead to fatigue and respiratory failure if left untreated, and pulmonary oedema may result from prolonged airway obstruction.

The common causes of airway obstruction are shown in Box 17.1. Laryngospasm and post-intubation oedema are considered in Chapter 19.

Clinical Presentation

Inspiratory stridor occurs when the obstruction is at or above the level of the cricoid ring. Expiratory stridor, wheeze and chest hyperinflation are found with lower intrathoracic obstruction (e.g., a foreign body).

Stridor is seen initially on exertion but, as the obstruction worsens, it occurs at rest. Children often prefer to sit, and there is hyperextension of the neck in an effort to prevent airway collapse. Chest recession and the use of the accessory muscles of respiration occur. Drooling results from a failure to swallow saliva. There is a gradual loss of interest in the surroundings and also a reduced level of consciousness (Box 17.2).

Diagnosis

A concise and relevant history with repeated, frequent observation of the child should be made. A history of *Haemophilus influenzae* type b (Hib) vaccination makes epiglottitis an

Box 17.1 Common causes of upper airway obstruction

- Congenital
- Acquired infective
 - laryngotracheobronchitis (croup)
 - epiglottitis
- Traumatic
 - burns/smoke inhalation
 - foreign body inhalation
 - post-intubation laryngospasm/oedema neoplastic

Box 17.2 Symptoms and signs of upper airway obstruction

- Stridor: inspiratory or expiratory
- Barking cough
- Hoarseness/voice changes
- Paroxysmal nocturnal dyspnea
- Chest recession
- Accessory muscle usage
- Sitting-forwards position
- Nasal flaring
- Hyperextension of neck
- Drooling
- Tachycardia
- Tachypnoea
- Cyanosis
- Loss of interest
- Reduced consciousness

unlikely, but not an impossible, diagnosis. Quiet observation of the child from a distance will often provide all the necessary information. Regular assessment of the work of breathing is key. The distressed and stridulous child should only be examined with caution, as any agitation or crying may precipitate a rapid deterioration of this situation. Throat examination and IV access may therefore be delayed in these cases. Gentle application of a saturation probe may be tolerated but more invasive laboratory tests such as arterial gas analysis can be too distressing and not helpful. It will certainly upset the child, exacerbate the condition and may delay treatment.

Exhaustion can occur rapidly and cyanosis is often difficult to detect and is a very late sign. If you have any doubts about the severity of the obstruction, admit the child to the intensive care unit and accompany the child yourself. Teamwork with the ENT surgeons and intensive care unit are key to management of these cases.

The phase of stridor – inspiratory versus expiratory or biphasic – may give an indication to the level of airway obstruction and potential causes, as outlined in Box 17.3.

Box 17.3 Phases of stridor

- Inspiratory – Above the cords
e.g. Croup, Epiglottitis
- Expiratory – Below the cords
e.g. Foreign body
- Biphasic – At or below the cords
e.g. Bacterial tracheitis, foreign body

Laryngotracheobronchitis (Croup)

Croup affects the whole respiratory tract, but oedema of the glottic and subglottic region causes the airway obstruction. The aetiology is:

- Most commonly caused by viral parainfluenza
- Other viral causes include respiratory syncytial, influenza viruses A or B, rhinovirus
- Bacterial causes such as *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Haemophilus influenzae*
- Spasmodic secondary to an allergy or reflux

The child (mean age about 18 months) usually has a history of an upper respiratory tract infection with moderate fever for 48 hours before the onset of stridor.

Stridor is often worse at night, and stridor at rest is an indication for hospital admission. The principles of care for severe cases include:

- Keep the child and parent calm
- Transfer the child to resus and minimise disruptive interventions
- Give supplementary oxygen
- Alert senior staff including anaesthetic consultant and ENT surgeon on call
- Administer dexamethasone 0.3–0.6mg/kg orally (max 16mg) or nebulised budesonide 2mg
- Consider administering nebulised adrenaline (1:1,000) 0.4ml/kg (max 5ml) every 1 to 4 hours
- Consider intubation and transfer to intensive care

Bacterial tracheitis, commonly from *Staphylococcus aureus*, requires antibiotic treatment (e.g., cefotaxime 50 mg/kg every 6 hours). Spasmodic croup occurs suddenly at night and may occur without a pre-existing infection.

Epiglottitis

This is caused mainly by *Haemophilus influenzae* type b infection and occurs in the 2- to 7-year-old age group.

The incidence has declined dramatically since vaccination programmes have been implemented. The history is typically short. There is a high fever, malaise, dysphagia, dysphonia, an absent cough and the stridor has a unique, low-pitched, snoring quality. The child will sit with an open mouth. Antibiotic therapy should be started and, if there is a high risk of obstruction, an a definite airway should be secured. If complete obstruction occurs before intubation, hand ventilation is usually possible despite the oedematous structures.

Foreign Body

Some foreign bodies will pass down into the bronchi, usually the right, but others will lodge in the larynx, causing obstruction and the risk of hypoxic arrest. The European Resuscitation Council recommends the following treatment:

- *Infants less than 1 year*: five back blows between shoulder blades with the head lower than the trunk and the child prone. If this does not work, five chest thrusts with the child supine can be given.

Table 17.1 Advantages of inhalational and IV induction

Advantages of using inhalational induction	Advantages of using IV induction
• Less invasive to an already distressed and agitated child • Slow onset may cause gentle induction with reduced risk of apnoea • Volatile agents may cause bronchodilatation and improve oxygenation	• Allows for rapid induction • IV access in place in case other drugs or emergency drugs need administering • A technique most anaesthetists are very familiar with • Depth of anaesthesia is not dependent on patency of the airway

- *Children more than 1 year:* if the above is unsuccessful, then abdominal thrusts with the child supine (Heimlich manoeuvre) can be performed.

In a life-threatening situation, a foreign body in the laryngeal area can be removed under direct vision using a laryngoscope and a pair of Magill intubating forceps. This should be attempted only by an experienced anaesthetist.

Management of Intubation

If a child is deteriorating, or unresponsive to treatment, tracheal intubation to bypass the obstruction must be undertaken.

The principles of management are as follows:

- Get HELP: an *experienced anaesthetist* is needed
- ENT surgeon should be present if possible (may need a tracheostomy)
- Transfer the child to theatre/Intensive Care Unit
- Supervise transfer and take resuscitation equipment
- Keep parents present and informed
- Full monitoring in place including capnography
- Prepare a range of tracheal tube sizes
- Plan and prepare airway management including Plan D
- Induction of anaesthesia may be IV or inhalational (see Table 17.1)

Traditionally these cases were managed using inhalational anaesthesia, however no consensus has been reached on this controversial topic. Choice of induction may be chosen depending on the child's condition, agitation, clinical expertise and likelihood of having a difficult airway. Some cases may therefore be more appropriate to receive an IV induction. Both techniques can have advantages.

Conclusion

Stridor is a medical emergency that needs assistance from an experienced anaesthetist. A trainee must know the principles of maintaining a patent airway in this situation. If you have any doubts about the severity of the obstruction, transfer the child to an intensive care unit and accompany him or her on transfer. Stay calm – you are dealing with a frightened child, very worried parents and a paediatrician who often knows less about an obstructed airway than you.

Pneumothorax

A pneumothorax is the presence of air within the pleural cavity. For it to occur, a communication must be present between the pleural cavity and either the tracheobronchial tree or the atmosphere by a defect in the chest wall. The main causes are shown in Box 18.1. An emergency arises when a tension pneumothorax develops. This is most likely to occur when intermittent positive pressure ventilation is applied to the lungs of patients with the following problems:

- undiagnosed spontaneous pneumothorax
- emphysema
- lung bullae
- asthma

It is important to remember that all patients have the potential to develop a pneumothorax in anaesthesia. The situation is exacerbated if nitrous oxide is used as it diffuses rapidly into gas-filled spaces and thus increases the size of any pneumothorax.

In a tension pneumothorax, air entering the pleural cavity is unable to return to the lung and increases the pressure in the hemithorax, causing lung collapse. The mediastinum is shifted across the midline, decreasing venous return and impeding cardiac output, with impaired ventilation to the other lung. This combination of major physiological changes is potentially lethal.

Box 18.1 Causes of pneumothorax

- Spontaneous
 - asthma, lung bullae, emphysema
 - Marfan's syndrome
- Iatrogenic
 - central venous catheters
 - surgery near the pleura (e.g., fundoplication, nephrectomy)
 - any laparoscopic surgery
 - barotrauma from prolonged intermittent positive pressure ventilation (IPPV)
- Traumatic
 - fractured ribs
 - other thoracic trauma

Box 18.2 Signs of pneumothorax in anaesthesia

- Unexplained cyanosis
- Wheeze
- 'Silent' chest on auscultation
- Difficulty with ventilation
- High airway pressures
- Sudden change in airway pressures
- Tachycardia
- Hypotension

The diagnosis is not easy, but should be suspected when the signs shown in Box 18.2 occur during or shortly after anaesthesia. The slowly developing pneumothorax may only manifest itself as hypotension which is resistant to intravenous fluids and vasopressors. Stay vigilant as the classical signs may only become apparent immediately before the cardiac output is lost.

Treatment

If time allows, a chest X-ray film in expiration will confirm the diagnosis although ultrasound is now increasingly used. Nitrous oxide should be discontinued. A chest drain must be inserted. In a life-threatening situation a 14-gauge cannula should be inserted into the pleural cavity to relieve the tension pneumothorax. This must then be connected to an underwater drainage system.

A chest drainage tube is inserted into the second intercostal space in the midclavicular line or the fifth intercostal space in the midaxillary line. It is important to insert the tube through a high intercostal space, as there is a risk of abdominal organ damage. A chest drain inserted through the liver will cause spectacular blood loss.

- Use an aseptic technique
- If patient is unanaesthetised, inject local anaesthetic from skin to periosteum
- Make 2–3 cm horizontal incision
- Make blunt dissection through the tissues until it is just over the top of the rib (the intercostal vessels lie beneath the rib)
- Puncture the parietal pleural with the tip of a clamp and put a gloved finger into the incision to avoid injury to any organs and to clear the area of any adhesions or clots
- Clamp end of tube and advance it through the pleura to the desired length
- Connect tube to chest drain – the underwater tube should be placed less than 5 cm into the water to minimise resistance
- Suture the tube in place and confirm position by a chest X-ray film

Conclusion

Pneumothorax is uncommon in anaesthesia but must be considered when certain signs arise unexpectedly during or after anaesthesia. It is particularly likely in operations in the renal area. A tension pneumothorax must be treated by the insertion of a chest drain or, if this is unavailable, a 14-gauge intravenous cannula may be used temporarily.

Common Intraoperative Problems

Problems occurring during anaesthesia and surgery must be considered in an appropriate way. For example, the onset of an arrhythmia during surgery may have an anaesthetic cause, or it may result from surgical stimulation.

A disturbance of cardiac rhythm is not necessarily indicative of myocardial disease. If the arrhythmia is accompanied by sweating and hypertension it probably results from excessive sympathoadrenal activity.

You must learn to consider the causation of intraoperative problems in the following order:

- anaesthetic
- surgical
- medical

Think like us. What have I done? What has the surgeon done? What has the patient done? In particular, we recommend that the following safety check is undertaken whenever an unexpected problem arises:

- Is the anaesthetic machine working correctly?
- Are the gas flows correct?
- Is the circuit assembled correctly and working?
- Is the airway patent?

This fundamental principle of an anaesthetic cause, before a surgical cause, before a medical cause, cannot be overemphasised. The simple mechanistic approach that a bradycardia needs intravenous atropine will be fatal if the slow heart rate is a response to hypoxaemia following a disconnection within the circuit. Identifying the site of the disconnection and oxygenating the patient is the obvious priority. Common causes of intraoperative problems are shown in Box 19.1.

Some problems remain after anaesthetic and surgical causes have been eliminated, and these need specific treatment.

Laryngospasm

Reflex closure of the glottis from spasm of the vocal cords is usually due to laryngeal stimulation. Common causes include insertion of a Guedel airway or laryngoscope, the presence of a tracheal tube and secretions in the airway. It can also arise as a response to surgical stimulation in a lightly anaesthetised patient. Thus, it occurs not only on induction of anaesthesia but also intraoperatively, and occasionally postoperatively.

The airway obstruction can lead to hypoxia, bradycardia and, in severe cases, pulmonary oedema can result.

Box 19.1 Common causes of intraoperative problems

- Anaesthetic
 - exclude HYPOXIA exclude HYPERCAPNIA
 - response to laryngoscopy and intubation?
 - correct gas flow settings?
 - correct use of volatile agents?
 - correct use of TIVA?
 - check pump function/settings
 - is venous access patent?
 - pain?
 - awareness?
 - correct drugs?
 - drug interactions?
 - adequate monitoring?
 - malignant hyperthermia?
- Surgical
 - reflex responses – eye, dental surgery, vagal stimulation? retractors correctly sited?
 - haemorrhage – occult?
- Medical
 - specific diseases – cardiac?
 - undiagnosed disease – phaeochromocytoma? electrolyte imbalance?
 - acid–base balance?

Treatment

The management of laryngospasm depends on its severity, as shown in Box 19.2.

There is a belief that a patient with severe laryngospasm and cyanosis will gasp a breath just before hypoxaemia is fatal. Do not try to verify this tenet – if in doubt paralyse and ventilate the patient.

Box 19.2 Management of laryngospasm

1. Identify stimulus and remove, if possible.
2. Give 100 per cent O₂ and get help.
3. Ensure patent airway.
4. Tighten expiratory valve to apply a positive airway pressure to 'break' the spasm and increase O₂ intake with each breath (BE CAREFUL NOT TO INFLATE THE STOMACH).
5. Consider deepening anaesthesia with an induction agent such as propofol.
6. If unable to ventilate, give a neuromuscular blocking drug, intubate the trachea and deepen anaesthesia. Ensure intubation and ventilation is feasible.

Box 19.3 Differential diagnoses of wheeze

- Oesophageal intubation
- Tracheal tube in right main bronchus
- Kinked tracheal tube
- Tracheal tube cuff herniation over end of tube
- Secretions in tracheal tube
- Secretions in trachea/lungs
- Gastric acid aspiration
- Pneumothorax
- Pulmonary oedema
- Bronchospasm

Wheeze

Wheeziness during anaesthesia may be caused by many factors other than bronchospasm (Box 19.3). These causes must be eliminated before treatment for bronchospasm is started. It is important to again think of the causes in the order of anaesthetic (tracheal tubes and equipment) and then patient (bronchi and lungs).

Complications associated with intubation often cause wheeze, and it is essential to check the position and patency of the tracheal tube first.

Treatment

Treatment of intraoperative bronchospasm is as follows:

- 1 Consider using a volatile agent.
- 2 Give salbutamol 250 µg slowly intravenously.
- 3 Give hydrocortisone 100 mg intravenously.

Aspiration

Several factors make patients more prone to vomiting and aspiration of gastric contents in anaesthesia. These include trauma, a full stomach, opioids, raised gastric pressure (bowel obstruction, pregnancy) and diabetes (autonomic neuropathy). Aspiration may be particulate or liquid and concealed, or obvious. Use of an appropriate anaesthetic technique (rapid sequence induction) safeguards patients most at risk.

Patients with wheeze must be suspected of having aspirated, and a postoperative chest X-ray may reveal a right lobe infiltrative pattern as aspiration usually occurs into the right lung.

Treatment

Treatment is aimed at securing the airway, aspirating the trachea and ensuring oxygenation. If aspiration is severe, surgery should be abandoned. Saline lavage of the trachea and bronchi has been used (but is unproven), antibiotics and steroids are also often used. The patient must be monitored closely postoperatively. Even a small volume of gastric aspirate (< 1 ml) may cause severe lung injury. Decisions about ventilation and extubation should be made with senior help. Postoperative physiotherapy may be useful.

Cyanosis

See Chapter 20.

Arrhythmias

Arrhythmias often occur in healthy patients undergoing anaesthesia. It is often difficult to interpret the ECG trace with only 6–7 beats observed on the screen. Atrial and ventricular ectopic beats are usually easily identified, but changes in P waves and ST segment changes may be hard to discern until extreme. Many modern monitors perform ST segment analysis routinely. Electrolyte abnormalities, especially hypokalaemia and hypomagnesaemia, should be checked for and treated.

Treatment

If any anaesthetic or surgical cause for the arrhythmia is eliminated and the rhythm disturbance remains, then four courses of action should be considered:

- 1 Observation + no treatment
- 2 Physical intervention
- 3 Drug treatment
- 4 Cardioversion

Pacing

Careful observation with no immediate treatment is commonly undertaken in patients with occasional atrial and ventricular ectopic beats who are cardiovascularly stable (normal blood pressure and no evidence of cardiac failure). Physical interventions, other than the removal of retractors that may compress the heart, consist of stopping the surgery when a vagal response, such as a severe bradycardia or even a brief asystolic episode, occurs. Arrhythmias are often transient, but they can age the novice anaesthetist – who will, briefly, wish for a career in dermatology! Carotid sinus massage and gentle pressure on the eye are ineffective treatments for supraventricular tachycardias found under anaesthesia. Careful preoperative assessment should identify those patients who may need pacing, and it is very unusual to need intraoperative pacing (complete heart block or symptomatic heart block). The drug treatments of life-threatening arrhythmias that we have found useful are summarised in Box 19.4. It is difficult to distinguish narrow and broad complex tachycardias during anaesthesia. A 12-lead electrocardiograph is needed, and this is often impractical during surgery.

For the tachyarrhythmias listed in Box 19.4, synchronised direct current (DC) cardioversion must be considered if there are signs of heart failure, if systolic blood pressure is less than 70 mmHg, or if there is a sustained heart rate of more than 150/min.

Hypotension

Intraoperative hypotension is common and usually results from an inadequate blood volume following haemorrhage. The major causes are either a decreased venous return or a direct depression of the myocardium due to mechanical causes, myocardial disease or anaesthetic drugs (Box 19.5).

Box 19.4 Drug treatment of life-threatening arrhythmias

- Sinus bradycardia
 - atropine 0.3 mg increments
- Narrow complex tachycardias
 - adenosine 6 mg rapid bolus followed by second dose of 12 mg within 1 minute, if necessary
 - if hypotensive, signs of failure and heart rate more than 200, give amiodarone 300 mg slowly and consider DC cardioversion
- Broad complex tachycardias (pulse present)
 - amiodarone 150 mg over 10 minutes

or

 - lignocaine (lidocaine) 50 mg over 5 minutes (repeated × 3)
- Sudden-onset atrial fibrillation
 - Beta blockers, magnesium or amiodarone (slowly)

Box 19.5 Major causes of intraoperative hypotension

- Decreased venous return
 - haemorrhage
 - vena caval compression – obstetrics, prone position
 - drugs, infection
 - anaesthesia without surgery
 - anaphylaxis
 - sepsis
 - epidural analgesia
- Myocardial depression
 - mechanical
 - intermittent positive pressure ventilation
 - equipment and circuit malfunction
 - pneumothorax
 - cardiac tamponade
 - pulmonary embolus
 - cardiac disease
 - drugs

Treatment

Treatment is dependent on correct identification of the cause. Rapid intravenous infusion of colloid or blood may be required, together with measurement of the central venous pressure. The use of inotropic drugs should be considered only when you are sure that there is an adequate circulating blood volume. Adrenaline is not an appropriate treatment for the hypotension of haemorrhage. Ensure that the hypotension is not a measurement error. Also check that there is not an excessive concentration of volatile agent.

Box 19.6 Causes of intraoperative hypertension

- Pre-existing hypertension
- Sympathetic stimulation
 - hypoxia, hypercarbia
 - inadequate level of anaesthesia, awareness
 - pain
 - raised intracranial pressure
- Iatrogenic
 - incorrect drug administration
- Rare causes
 - malignant hyperthermia
 - pheochromocytoma

Hypertension

Hypertension can occur from many causes, and these are listed in Box 19.6.

Treatment

Treatment is based on finding the cause of hypertension. Lack of analgesia or anaesthesia are the commonest causes. Ensure that the measurement is correct before starting treatment.

Conclusion

Many problems occur during the induction and maintenance of anaesthesia, and during recovery of a patient. Whatever the problem, a cause must be sought in the following sequence: anaesthetic > surgical > medical. Only when the first two have been eliminated should specific medical therapy be started.

Postoperative Problems

Intraoperative problems described in the previous chapter (laryngospasm, wheeze, pulmonary aspiration, cyanosis, arrhythmias, hypotension, hypertension) may continue, or even start, in the postoperative period. Investigation of the cause and subsequent management of these problems is identical, regardless of the time of onset.

Airway Obstruction

Obstruction of the airway is a common occurrence after anaesthesia. It must be rapidly diagnosed (Box 20.1), the cause sought (Box 20.2) and appropriate treatment started.

During emergence from anaesthesia patients may have pharyngeal and laryngeal muscle weakness, causing airway obstruction. Hypoxaemia will result if the airway is not maintained. Patients are turned routinely into the lateral or 'recovery position' to help prevent this problem. The patient is usually placed in the left lateral position, as reintubation is easier because laryngoscopes are designed to be inserted into the right side of the mouth. Curiously, most anaesthetists sleep in the recovery position.

If there is a possibility that aspiration may have occurred with the patient in the supine position, then he or she should be placed in the right lateral position to prevent contamination of the left lung.

Patients who are at risk of aspiration should be extubated when the airway reflexes are intact. Although this is less pleasant for the patient, it is much safer.

The treatment of airway obstruction is to identify the cause, and clear the airway, often with suction, to ensure patency. Extension of the neck, jaw thrust and insertion of an

Box 20.1 Signs of airway obstruction

- 'See-saw' respiration pattern
- Suprasternal and intercostal recession
- Tachypnoea
- Cyanosis
- Tachycardia
- Arrhythmias
- Hypertension
- Anxiety and distress
- Sweating
- Stridor

Box 20.2 Common causes of postoperative airway obstruction

- Anaesthesia
 - unconsciousness with obstruction by tongue
 - pharyngeal muscle weakness
 - laryngeal oedema
 - laryngospasm (Chapter 18)
- Surgery
 - vocal cord paralysis (thyroid surgery)
 - neck haematoma
 - preoperative neck and face inflammation (infection)

Box 20.3 Common causes of failure to breathe

- Central nervous system
 - depression from drugs e.g., opioids
 - inhalational agents decreased respiratory drive e.g., hypocapnia, COPD
- Peripheral nervous system
 - failure of neuromuscular transmission
 - inadequate reversal of non-depolarising neuromuscular blocking drugs
 - overdose of non-depolarising neuromuscular blocking drugs
 - plasmacholinesterase deficiency

oropharyngeal airway are often required. Laryngeal oedema is treated by intravenous dexamethasone 8 mg. Oxygenation of the patient is the priority, and, if you are in doubt, reintubation must be undertaken. Many problems in anaesthesia are caused by inadequate attention to the airway. Remember, a patent airway is a happy airway.

Failure to Breathe

Failure to breathe adequately at the end of anaesthesia has many causes, both common (Box 20.3) and unusual (Box 20.4).

Differentiation between central and peripheral causes of failure to breathe can only be made by using a nerve stimulator. A peripheral nerve, such as the ulnar nerve at the wrist, is stimulated. Ensure that the nerve stimulator is working correctly.

Adequate return of neuromuscular function is assessed by observing a train of four (TOF) pattern of stimulation. Four twitches delivered over 2 seconds (i.e., at 2 Hz) should be assessed. The gold standard is that the ratio of twitch 4 : twitch 1 response must exceed 90%. This cannot be assessed visually and requires the use of acceleromyography or electromyography (see Chapter 10). A sustained tetanic response following high-frequency stimulation (5 seconds at 5 Hz) has also been claimed to correlate with adequate neuromuscular

Box 20.4 Unusual causes of failure to breathe

- Hypothermia
- Drug interactions
 - Magnesium, aminoglycosides with NMJs
- Electrolyte disorders
 - Hypokalaemia, hypocalcaemia, hypermagnesaemia, hypophosphatemia
- Undiagnosed skeletal muscle disorders myasthenia gravis
- Extensive spinal anaesthesia in combination with general anaesthesia
- Central nervous system causes
 - Epilepsy, stroke, central anticholinergic syndrome, cerebral oedema (e.g., prolonged Trendelenburg position), serotonin syndrome functional coma, cerebral hypoxia

Box 20.5 Signs of adequate neuromuscular function

- Clinical responses are unreliable and often require a conscious patient (e.g., coughing)
- Evoked responses
 - absence of fade, with train-of-four ratio >90 per cent
 - sustained tetanic response to high-frequency stimulation

function, but clinical tests such as head lift, coughing are no longer recommended as they are unreliable tests to confirm adequate neuromuscular function (Box 20.5).

If inadequate neuromuscular function is confirmed, the lungs must be ventilated and the use of neuromuscular blocking drugs/reversal reviewed. Prolonged apnoea after suxamethonium occurs when the patient has an abnormal genetic variant of the plasma enzyme pseudocholinesterase. The patient and members of the family should be investigated at a later date, and susceptible individuals asked to carry warning cards.

Only when you are certain that neuromuscular transmission is normal should a central cause for failure to breathe be considered. Again the lungs must be ventilated, a normal end-tidal CO₂ concentration obtained and possible causes assessed (Box 20.3).

An overdose of opioid is a common reason for failure to breathe. This can be treated with low bolus doses of intravenous naloxone 10 µg, but this potent antagonist is short-acting and the return of adequate respiration is usually accompanied by a complete lack of analgesia! This is an unsatisfactory mess and it is better to ventilate the lungs until the central depressant effects of the drugs have worn off. Sugammadex can rapidly reverse the muscle relaxation caused by rocuronium and vecuronium. The list of central nervous system causes sound very worrying but are fortunately rare!

Postoperative Nausea and Vomiting

Postoperative nausea and vomiting (PONV) is a particularly unpleasant complication of anaesthesia and surgery. The avoidance of these problems is more important to some patients than the provision of adequate analgesia. There are many factors associated with

the occurrence of PONV (Box 20.6). This long list indicates that often there is no single identifiable cause, although opioids are frequently at fault.

Because patients find nausea and vomiting distressing, it should be prevented if possible. The medical consequences of vomiting include the possibility of acid aspiration, electrolyte imbalance and dehydration, inability to take oral drugs and disruption of the wound. A vomiting patient also upsets other patients in the recovery area and surgical ward.

Most anaesthetists prescribe prophylactic antiemetics. Drugs used include ondansetron, dexamethasone, cyclizine, droperidol and metoclopramide. A combination of antiemetics is useful, with each agent probably reducing PONV by 20–25 per cent.

Many anaesthetists will recommend a TIVA over a volatile based technique in patients with a history of severe PONV.

Delayed Awakening

Failure to recover full consciousness after surgery is always worrying for the anaesthetist. A wider systematic review of the patient is necessary (Box 20.7). There is much overlap with Box 20.4.

Box 20.6 Factors associated with PONV

- Patient predisposition
 - age, sex, menstrual cycle, obesity
 - history of postoperative vomiting
 - history of motion sickness
 - anxiety, pain
 - recent food intake, prolonged fasting
- Surgical factors
 - type of surgery, e.g., squint repair and laparoscopic surgery
 - emergency surgery
- Anaesthetic factors
 - inhalational agents and nitrous oxide
 - opioids
 - duration of anaesthesia
 - distension of gut
 - oropharyngeal stimulation
 - experience of anaesthetist
- Postoperative factors
 - pain
 - hypotension
 - hypoxaemia
 - movement of patient
 - first intake of fluids/food
 - early mobilisation

Box 20.7 Causes of delayed recovery

- Hypoxaemia
- Hypercapnia
- Residual anaesthesia especially after prolonged surgery
- Drugs, especially opioids
- Emergence delirium from ketamine, scopolamine, atropine
- Central nervous system causes, see Box 19.4
- Surgery: neurosurgery, vascular surgery
- Metabolic causes
- Hypoglycaemia, hyponatraemia
- Medical causes
 - hypothyroidism
- Sepsis
- Hypothermia

The most common causes are drug-related, but you must also remember the possibility of a low temperature, low blood glucose, low plasma sodium and low circulating thyroid hormones.

Shivering

Shivering is common during recovery from anaesthesia, but is not obviously related to a low core temperature in the patient. It is more frequent in young men who have received volatile agents. The main deleterious effect of shivering is an increase in O_2 consumption, and lactic acidosis if prolonged. This is of little consequence in young, fit patients, but it should be treated promptly in the elderly, who often have impaired cardiac and respiratory function.

Pethidine 25 mg intravenously is effective in stopping shivering; other opioids can also be used and some advocate other drugs too (e.g., clonidine and doxapram). The simple application of heat to the 'blush area' (the face and upper chest) can be tried to stop shivering. This indicates the importance of skin temperature in stimulating shivering, as the effect on body temperature is negligible.

Temperature Disturbances

A decrease in body temperature is an inevitable accompaniment of anaesthesia. Indeed, it has been noted that the most effective means of cooling a person is to give an anaesthetic. Hypothermia (defined as a core temperature less than 35°C) can occur after major surgery, and the predisposing factors are shown in Box 20.8.

Complications of postoperative hypothermia may include shivering (see above), impaired drug metabolism and decreased platelet aggregation. There are several methods available for preventing loss of body heat during surgery (Box 20.9), and a combination of treatments is necessary. For example, the theatre temperature must be maintained at 24°C , the inspired gases humidified, the intravenous fluids warmed and the skin surface warmed.

Hyperthermia after anaesthesia is uncommon. Of the causes listed in Box 20.10, infection is the most common and patients will require immediate intravenous antibiotics

Box 20.8 Factors predisposing to postoperative hypothermia

- Ambient theatre temperature
- Age: young and elderly
- Surgery
 - duration
 - size of incision
 - insulation
- Concomitant disease
- Intravenous fluid administration
- Drug therapy such as vasodilators

Box 20.9 Prevention of body heat loss

- Ambient theatre temperature
- Airway humidification
- Warm skin surface
 - passive insulation
 - active warming
 - radiant heater
 - forced air warmer
- Warm intravenous fluids

Box 20.10 Causes of hyperthermia

- Infection
- Environmental
- Mismatched transfusion
- Drugs
 - interactions
 - atropine overdose
- Metabolic
 - malignant hyperthermia
 - pheochromocytoma
 - hyperthyroidism

appropriate to the presumed bacteria (e.g., urinary tract or biliary tract). The potentially lethal complication of malignant hyperthermia should be diagnosed only after arterial gas analysis and determination of circulating potassium values (see Chapter 15).

Cyanosis

Cyanosis is a serious sequela of anaesthesia and, whenever it occurs, must be investigated promptly. Check for patent airway. If intubated, is tracheal tube correctly positioned and patent? Check oxygen delivery from anaesthetic circuit. Having excluded these causes, consider:

- Fault in chest (is ventilation easy?)
 - bronchospasm
 - pulmonary oedema
 - pneumothorax
 - pleural effusion/haemothorax
- Fault in circulation
 - decreased venous return
 - cardiac failure
 - embolism
 - drug reaction
- Rare causes include:
 - methaemoglobinaemia
 - malignant hyperthermia

Problems of the airway are the most common causes of cyanosis, and you must be certain that the airway is patent and the patient is receiving 100 per cent oxygen before considering other causes. Unless the situation is rapidly diagnosed and corrected the patient will need urgent tracheal intubation, ventilation with 100 per cent oxygen and resuscitation along conventional guidelines. Remember pneumothorax and cardiac tamponade, especially if the patient has undergone central line insertion. Both require specific (and life-saving) therapy. In cases associated with circulatory changes, fluids and/or sympathomimetics may be required.

Conclusion

Postoperative problems often reflect errors of judgement made during surgery. Get it right intraoperatively and your patients will have fewer difficulties postoperatively. Nursing staff in the recovery area and surgical wards rapidly assess your anaesthetic skills by the smoothness of recovery of your patients.

Anaesthetic Mishaps

In previous chapters we have described the management of problems that a trainee anaesthetist would be expected to recognise and treat. Unfortunately, errors made by the anaesthetist also result in morbidity and occasionally even mortality.

We give examples below of common mistakes made by anaesthetists, young and old, that we have seen in recent years.

Intravenous and Arterial Cannulae and Infusions

Ensure that the intravenous cannula is in the vein! Although this states the obvious, we keep seeing examples of cannulae that are subcutaneous and even in the dressing. If the patient arrives in the operating theatre with an intravenous cannula in place, remove all the dressings, examine it carefully and check for patency by flushing with 0.9% sodium chloride solution. If in doubt, insert another cannula. The cannula for total intravenous anaesthesia (TIVA) must be in a vein. Total subcutaneous anaesthesia is not effective and the patient will be aware! Always ensure that you have easy access to the infusion line for drug administration, such as a three-way tap. Arms by the side can cause problems. Never attach a pressure bag to a drip that is running slowly – if the drip tissues you will rapidly fill the compliant subcutaneous tissue with copious amounts of fluid. Also ensure the cannulae are flushed at the end of the case; even a small amount of neuromuscular blocking drug (NMBD) can be disastrous in the dead space if flushed into circulation several hours later (e.g., on the ward).

When inserting a cannula, do not place the introducing needle on the patient or trolley. A needle-stick injury to the anaesthetist, theatre, recovery or ward staff will ensure that you are omitted from all future social events. Fortunately many cannulae (not all) now have a needle safety guard which automatically covers the bevel after withdrawal of needle from the hub.

Anaesthetists often have two speeds for intravenous infusions: off and full open. The ‘full open’ infusion is a problem if additions have been made to the infusion fluid. The rapid infusion of 20–40 mmol potassium is bad for the health of both patient and anaesthetist.

Arterial cannulae should always be flushed with 0.9% sodium chloride solution, not glucose solutions. When taking a sample from an arterial cannula for blood gas analysis ensure that sufficient dead space is removed from the cannula. Failure to do so will result in spuriously high sodium, low potassium, low haemoglobin concentrations and a metabolic acidosis from contamination with sodium chloride. We have known patients to be treated inappropriately on the basis of incorrect blood gas results – infusion of potassium or red blood cells. Patients have also died from spuriously high glucose levels treated with large

amounts of insulin, only to discover that the flushing solution was glucose not 0.9% sodium chloride. When rechecked from another site, the blood glucose was unrecordable.

If the arterial pressure suddenly looks abnormally high, check the position of the transducer – it may be on the floor! Do not treat with vasodilators!

Drugs

All syringes must be labelled correctly. For example, recently a 2 ml syringe containing suxamethonium was labelled incorrectly as antiemetic. Patients do not expect to have nausea and vomiting treated by the rapid onset of paralysis.

Atropine and adrenaline are often stored next to each other in the drug cupboard, and the wrong drug has been drawn up by an inexperienced assistant in an emergency.

It is easy to forget to add the drug to the solvent. One author has, on two occasions, failed to add the vecuronium to the diluent and waited for the onset of paralysis for many minutes. Emergency drugs, suxamethonium and atropine, should be checked and drawn up (or immediately available in prefilled syringes) at the beginning of the list. It is easy to assume that they are readily available. One author had the alarming experience of a patient suddenly developing severe sinus bradycardia from direct vagal stimulation (less than 30 beats/min) with no atropine available in the theatres. Fortunately, the patient survived – but the mistake has never been repeated.

It is also wise to have ephedrine and a vasopressor (e.g., phenylephrine or metaraminol) to hand as induction of anaesthesia is very often associated with hypotension. Remember that drugs are locked away and ensure that these are unlocked (including the drug fridge) at all times when the patient is in theatre.

Anaesthetic Machine and Equipment

It is important to remember that with machines and equipment, if anything can go wrong, it will go wrong. You are surrounded in life by examples of technical failures. They will follow you into the operating theatre.

Anaesthetic tubing invariably becomes disconnected at the most inconvenient time. Modern anaesthetic machines can be fraught with problems. Some ventilators require the 'on' switch to be held down for a few seconds to start. In the circle system there is often a switch for spontaneous ventilation and controlled ventilation. Always keep a self-inflating (AMBU) bag on the machine so you can use this when all else fails. Some machines have an auxiliary common gas outlet (ACGO) for attaching another circuit – typically Mapleson E and F systems (Ayre's T-piece and the Jackson Rees modification) – for paediatric patients. In a mixed list of children and adults it is easy to attach the patient to a circuit with no fresh gas flow.

Vaporisers are often the source of problems. They must be filled at the start of the list.

Ensure that all ancillary equipment functions correctly. The failure to have spare laryngoscopes with bulbs that work and the failure to replace suction equipment after use have resulted in the unnecessary deaths of patients. Checking the equipment is your responsibility.

Monitoring Equipment

Monitoring equipment fails occasionally, and can also display misleading values. A spare set of monitoring equipment must always be available. Always support the information given

by the monitors with direct observation of the patient. Assume that the monitoring will fail at the most inappropriate time. One author had a complete failure of all intravascular pressure measurements during anaesthesia for a pheochromocytoma.

Some anaesthetists disable the alarms on the monitor. This is stupidity. Ensure that alarms are on and set within sensible limits. With gas analysis and minimum alveolar concentration (MAC) displayed, you will know that your patient is breathing correct quantities of oxygen and is properly anaesthetised. Remember not to rely on pulse oximetry unless you have a good plethysmograph trace – we have seen good SpO₂ readings with the probe on the pillow.

Tracheal Tubes

Very occasionally you will be certain that you saw the tube pass between the vocal cords into the trachea and yet you have inserted the tube into the oesophagus. Because you are sure that the tube is in the correct place, you try to explain the failure to ventilate the lungs as a problem with the patient, for example bronchospasm. We know of at least four occasions on which this error has occurred. If the mistake is not rectified the patient will die. If in doubt, remove the tube, ventilate the patient and reinsert the tube correctly. Tracheal tubes can also be inserted too far, kink and become obstructed.

Epidural Anaesthesia

Epidural catheter sets can have manufacturing faults. The most common is the absence of holes in the end of the epidural catheter so that it is impossible to inject drugs. Many drugs have been given in error through the epidural catheter. Antibiotics and thiopentone are particular favourites, as they are usually in a 20 ml syringe, the same volume as the local anaesthetic. Be particularly careful when the epidural catheter and filter are placed next to the central venous cannula. Conversely, local anaesthetic solutions have been given intravenously in error, causing convulsions and even death. Always be wary of someone else's epidural – assuming that it is in the epidural space can lead to total spinal anaesthesia after a top up!

Transfer of Patients

Ensure that the patient is adequately anaesthetised before transfer from the anaesthetic room into theatre. Failure to do so results in a shambles. One author recently had the patient sit up in theatre, remove the laryngeal mask and hand it to the surgeon! Try to avoid being the cabaret act in theatre.

Similarly, transfer to the recovery area at the end of surgery can also degenerate into chaos. A violent patient with an obstructed airway is not easy to sort out in the corridor. Stay in theatre until you are sure that the patient is safe.

Theatre Environment

There are many distractions in theatre. Keep all unnecessary people out of the anaesthetic room. It should not be used as a venue for social intercourse – the nocturnal habits of Stephanie and Steven may be interesting but will divert your concentration away from the patient. Music in the theatre may interfere with hearing the alarms on the anaesthetic

machine or monitoring equipment. If so, the music must be turned down or off. Mobile phones distract from the patient and should be turned off.

Conclusion

Get used to continually checking and re-checking the patient and monitors. Ensure you have good access to the patient's airway and intravenous cannula. Pay particular attention to the expired CO₂, SpO₂, ECG, blood pressure and MAC values. Never be frightened to share your concerns with theatre staff – all will rally to your support. Anaesthesia has the uncanny habit of humbling overconfident, arrogant anaesthetists who believe that they never make mistakes.

Unfortunately, simple mistakes can kill patients.

Section**3**

Passing the Gas

As the weeks of your anaesthetic career become months, you will play a larger role in the preoperative assessment of patients and the conduct of the anaesthetic.

In this section of the book we describe briefly the anaesthetic considerations of some of the common surgical specialities with which a trainee is often involved. There is very rarely any good evidence to show sustained benefit to the patient from a particular anaesthetic technique in terms of postoperative morbidity, mortality and longer-term survival. The principles of anaesthesia are more important than the choice of drugs, and your focus is to ensure the patients' short-term survival (i.e., on the operating table)

The key feature of this section is the need for a thorough preoperative evaluation of all patients. This is the cornerstone of safe anaesthetic practice and must never be omitted.

Preoperative Evaluation and Preparation

Preoperative assessment has undergone a huge transformation in the last few years. Much happens prior to the day of admission and is undertaken remotely or face-to face by questionnaires overseen within nurse-led preoperative assessment clinics. Depending on the magnitude of surgery and the health of the patient there are a number of scenarios:

- (a) The patient may require an online/telephone assessment only
- (b) The patient may require a face-to-face appointment, often with some supplementary investigations
- (c) The patient may be identified as high risk. These patients should see a consultant anaesthetist in the high risk anaesthetic clinic (HRAC)
- (d) The patient may require further detailed tests (e.g., cardiopulmonary exercise testing – (CPET))
- (e) The patient may require specific preparation, for example, prehabilitation, intravenous iron, attend joint school prior to joint surgery, assistance with drug and alcohol modification, or other surgery prior to the planned surgery (e.g., percutaneous coronary intervention (PCI) prior to non-cardiac surgery)

The fundamental principle of preoperative assessment is to reduce perioperative risk by ensuring the patient is as well as they can be made prior to surgery. This is achieved by triage which risk assesses patients into low, medium and high risk categories. Low risk patients pass rapidly through the process, whilst the higher risk patients are identified and receive detailed analysis, planning and preparation preoperatively with both the patients and their families.

Special facilities need to be in place for children and young persons, patients with frailty, learning disabilities, drug misusers, those with limited IT access and skills and those for whom English is not their first language. Finally, preassessment must be carried out in good time prior to surgery, and patients contacted again if there are long delays prior to the surgery, with as many aspects of the process coordinated to minimise hospital visits for the patient as well as minimise on-the-day cancellations.

Preoperative evaluation therefore provides the opportunity to:

1. Assess the anaesthetic risks in relation to the proposed surgery.
2. To decide the anaesthetic technique (general, regional or a combination with appropriate monitoring).
3. To aid decisions about the suitability of surgery (major or palliative).
4. To medically optimise the patient.
5. To plan postoperative care, including any analgesic regimens and location of care (e.g., day case, ward, HDU or ICU).

- 6 To provide the patient and their family with information about the above and discuss this. Sometimes patients have misconceptions such as sedation and/or regional anaesthesia is safer, which may not be true (and is often impossible/impractical, such as a spinal block for laparoscopic surgery)

Patients waiting for surgery are vulnerable, and therefore a friendly, professional approach by the anaesthetist is essential. Surgical risk factors and patient risk factors should be considered.

Surgical Risk Factors

Operations can be graded according to perioperative cardiac risk as follows:

- High risk (5% +) open major vascular, intrathoracic and open abdominal
- Intermediate risk (1–5%) head and neck, neurosurgery, arthroplasty
- Low risk (1%) breast, minor orthopaedic, minor urology

Patient Risk Factors

You may encounter several risk assessment tools that vary in complexity and usefulness. Many are available online or as an app. These include the Lee Revised Index, P-POSSUM, NELA, SORT and ACS-NSQIP (as described in Chapter 11). A commonly used score is the Lee Revised Index, which has six criteria as follows:

1. High risk surgery – see above
2. Ischaemic heart disease
3. Congestive cardiac failure
4. Cerebrovascular disease
5. Insulin-dependent diabetes
6. Serum creatinine greater than 176 micromol/l

Operations are classified into four groups that define the urgency of the surgery (Box 22.1). This classification has been agreed with the surgeons, but their memory often fails, so do not be surprised to find elective cases suddenly classified as emergencies! This is usually done for surgical convenience.

It is sometimes difficult to convey an overall impression of the complexity of a patient's medical condition, and this can be done by referring to one of the five American Society of Anesthesiologists (ASA) physical status classes (Box 22.2). It is important to remember that this only refers to the physical status of the patient and does not consider other relevant factors such as age, and nature and duration of surgery.

Preoperative assessment is outlined below:

1. History
 - age
 - present illness
 - drugs
 - allergies
 - past history (operations and anaesthetics)
 - anaesthetic family history
 - social (smoking, alcohol)

Box 22.1 Classification of operations

- | | |
|-------------|---|
| • Immediate | Immediate life-, limb- or organ-saving intervention – resuscitation simultaneous with intervention. Normally within minutes of decision to operate. (A) life-saving; (B) other, e.g. limb- or organ-saving |
| • Urgent | Intervention in response to acute onset or clinical deterioration of potentially life-threatening conditions, for those conditions that may threaten the survival of limb or organ, for fixation of many fractures and for relief of pain or other distressing symptoms. Normally within hours of decision to operate |
| • Expedited | Patient requiring early treatment where the condition is not an immediate threat to life, limb or organ survival. Normally within days of decision to operate |
| • Elective | Intervention planned or booked in advance of routine admission to hospital. Timing to suit patient, hospital and staff |

Box 22.2 ASA physical status classes

- | | |
|---------|---|
| • ASA 1 | normal healthy patient |
| • ASA 2 | patient with mild controlled systemic disease that does not affect normal activity, e.g., mild diabetes, mild hypertension. In addition it includes those who smoke, social alcoholic intake and BMI of 30–40. |
| • ASA 3 | patient with severe systemic disease which limits activity, e.g., angina, chronic bronchitis, as well as history (>3 months) of MI, CVA, TIA, or CAD/stents |
| • ASA 4 | patient with incapacitating systemic disease that is a constant threat to life, e.g., history (<3 months) of MI, CVA, TIA, or CAD/stents, current angina, low ejection fraction, severe cardiac valve dysfunction |
| • ASA 5 | moribund patient not expected to survive 24 h either with or without an operation |
| • E | emergency procedure |

2. Examination

- AIRWAY (see Chapter 1)
- teeth

3. general examination

4. specific assessment

5. investigations

6. consent

7. premedication, if required

The history of the present illness is important. For example, in orthopaedic surgery, a fractured neck of femur may occur for many reasons: a fall from an accident, stroke, cardiac episode (Stokes–Adams attack) or a spontaneous fracture from a metastasis.

The subsequent examination and investigations are obviously different in each case. Details of any previous anaesthetics may indicate difficulties with tracheal intubation. Unfortunately, successful intubation in the past is no guarantee of future success. A family history of pseudocholinesterase deficiency and malignant hyperthermia should be sought.

A specific assessment of the concurrent disease(s) must also be undertaken. The problem of obesity (BMI > 30) is evaluated as shown in Box 22.3.

Only appropriate investigations should be undertaken. A typical list of basic tests is shown in Box 22.4. A lot of money is wasted on unnecessary preoperative tests. When you have taken a history from the patient and conducted the relevant examination, you must then decide what tests, if any, are required. A young, fit sportsman for an arthroscopy requires no further investigation. An elderly West Indian patient who has diabetes, hypertension, coronary artery disease, and needs major vascular surgery, requires all the basic tests listed in Box 22.4 and probably more. In many hospitals there are guidelines on the use of preoperative investigations. These can be helpful, as they reflect local practice. For example, you may find that there is far greater use of preoperative chest X-ray films in regions with a high population of recent migrants, to exclude tuberculosis.

Occasionally, it is necessary to postpone surgery. This is most often done on medical grounds, for example to improve cardiac failure, treat arrhythmias and control blood pressure. In the early months of your anaesthetic career, seek senior advice before postponing surgery – this prevents prolonged arguments with surgical colleagues.

Box 22.3 Specific assessment of obesity

- Psychological aspects
- Drug metabolism
- Associated diseases e.g., hypertension, coronary artery disease, diabetes
- Difficult venous access
- Airway and lungs:
 - difficult to intubate trachea
 - more likely to have oesophageal reflux
- Hypoxaemia more likely intraoperatively – ventilation mandatory
- Regional anaesthesia – difficult to perform
- Position of patient for surgery
- Blood pressure measurements difficult (cuff size)
- Postoperative analgesia and physiotherapy to decrease chest complications
- Immobility and deep vein thrombosis – prophylaxis
- Wound dehiscence and wound infection

Box 22.4 Basic and advanced preoperative tests

- Basic
 - haemoglobin concentration, screening for sickle cell disease
 - blood urea, creatinine and electrolyte concentrations, blood glucose, HbA1c if diabetic
 - chest X-ray film, ECG
- Advanced
 - respiratory function tests
 - echocardiography, angiography or cardiac MRI
 - arterial blood gases, clotting profile
 - liver function tests
 - cardiopulmonary exercise testing
 - test for obstructive sleep apnoea (sleep studies and serum bicarbonate)

Box 22.5 Reasons for premedication

- Anxiolysis
- Antisialagogue
- Analgesia
- Antiemesis
- Amnesia
- Decreased gastric acidity
- Part of anaesthetic technique (assist induction)
- Prevention of unwanted vagal responses
- Prevention of needle pain

Premedication

The use of premedication is declining. Appropriate timing for preoperative drug administration can be challenging and unwelcome sedative effects may carry into the postoperative period. Many patients dislike the premedication too, for reasons including it causing a dry mouth, dysphoria, and so on. Interestingly, many anaesthetists undergoing surgery demand heavy sedation. The wishes of the patient must be considered. The main reasons for giving premedication are shown in Box 22.5.

A variety of drugs including opioids, benzodiazepines, anticholinergics, phenothiazines and H₂ receptor blocking drugs are used. It is important to remember that opioids may make patients vomit. Topical EMLA cream can be used to prevent the pain of insertion of a cannula. This eutectic mixture of prilocaine and lignocaine (1 g of EMLA contains 25 mg of each) is applied to the dorsum of the hands for a minimum of 1 hour to a maximum of 5 hours before induction of anaesthesia.

Drug Therapy

Drug therapy is usually continued throughout the operative period, especially cardiac and antihypertensive drugs. Notable exceptions are the hypoglycaemic drugs and drugs affecting clotting such as clopidogrel, warfarin and direct acting oral anticoagulants (DOACs). Patients taking oral contraceptives and hormone replacement therapy may require thromboprophylaxis with subcutaneous low-molecular-weight heparin and graduated elastic compression stockings. Key drugs to consider are:

- Antihypertensives
- Cardiac drugs
- Steroids
- Hypoglycaemic drugs/insulin
- Anticoagulants and antithrombotics
 - aspirin
 - warfarin
 - clopidogrel
 - heparin
 - DOACs

Decisions about continuing or stopping drugs should have been made at the preoperative assessment clinic. However, patients cannot be relied on to remember, so check carefully that they have complied with their instructions. Some higher risk patients require conversion from longer acting anticoagulants which are stopped, following which they are then 'bridged' with shorter acting anticoagulants such as heparin to minimise the risk of both preoperative thrombosis and perioperative bleeding.

Preoperative Starvation

An empty stomach decreases the risk of vomiting and regurgitation. Food is usually withheld for 6 hours before elective surgery and in some hospitals it is now common practice to allow clear fluids until 1–2 hours before surgery, or even until the time the patient is sent for ('sip til send'). For emergency surgery these guidelines are inappropriate, and the only safe practice is to assume that the stomach is not empty (see Chapter 23).

Recently the use of some drugs used for managing weight loss (and diabetes) such as glucagon-like peptide-1 receptor agonists (GLP-1RA) have been associated with delayed gastric emptying.

When to Ask for Advice

A common difficulty for the trainee is when to ask for advice and assistance. We suggest that if you need advice, state that you are ringing for advice. If you need a senior member of the team to be present you should say so.

If in doubt, it is always better to inform seniors of the problems and your decisions. Often two minds are better than one, and senior anaesthetists need to know what is happening in the department, especially out of routine working hours.

Conclusion

Preoperative assessment is often difficult, and its importance should not be underestimated. The anaesthetic care of the patient can only be planned after a thorough assessment, together with the results of relevant investigations, and precise knowledge of the proposed surgery. Where possible the patient and their relatives should be involved in any decision-making process (Shared Decision-Making – see Chapter 11). In emergency surgery, ask the question ‘can the patient be made significantly better? If so, does time allow for this?’

General Principles of Emergency Anaesthesia

You will be introduced to emergency surgery at an early stage in your career. Most hospitals have an emergency theatre staffed 24 hours, 365 days per year. In elective surgery, the correct diagnosis has been made (usually), any medical disorders have been identified and treated and an appropriate period of starvation has been determined. During emergency work, however, one or more of these conditions are often not met. In addition, there are further problems such as:

- Dehydration
- Electrolyte abnormalities
- Haemorrhage
- Pain
- Sepsis
- Other physiological systems impairment (kidney, liver, coagulation, CNS etc.)

The components of general anaesthesia are the same, whether it is conducted for elective surgery or emergency surgery (Box 23.1).

The key to success in emergency anaesthesia is a thorough preoperative assessment. It should be undertaken as described in Chapter 22. Particular attention must be given to medical problems, the occurrence of hypovolaemia and an evaluation of the airway. On the basis of the preoperative clinical assessment, together with the results of relevant investigations, a decision for an appropriate time to operate can be reached.

There are very few patients with a potentially life-threatening clinical state that need immediate surgery, that is, a true 'emergency' (see Box 22.1). The majority of patients greatly benefit from the correction of hypovolaemia and electrolyte abnormalities, stabilisation of medical problems, such as diabetes and cardiac arrhythmias, and waiting for the stomach to empty.

Box 23.1 Components of general anaesthesia

- Preoperative assessment
- Premedication, if any
- Induction
- Maintenance
- Reversal
- Postoperative care

Box 23.2 Anaesthetic techniques for emergency surgery

- General anaesthesia
 - with intubation of unprotected airway
 - spontaneous respiration or controlled ventilation
 - use of muscle relaxants
- Regional anaesthesia
- Combination of general and regional anaesthesia
- Sedation
 - intravenous
 - inhalational
- Combination of sedation and regional anaesthesia

If necessary, preoperative optimisation should be undertaken in ICU. Surgeons are not known for their patience and often view any delay in operating as time wasted. When to operate is the most important decision that has to be made in emergency work. Fortunately, for the patient, and for you, increasingly this decision is made by senior staff. In the early stages of your anaesthetic career you should observe closely the evidence used to reach such a decision.

Although it is usually assumed that emergency anaesthesia means general anaesthesia, other methods can sometimes be employed (Box 23.2).

There is increasing use of regional anaesthesia, but hypovolaemia must be corrected preoperatively and it is contraindicated in patients with a coagulopathy or sepsis. Sedation should not be confused with general anaesthesia. The sedated patient can talk to the anaesthetist at all times. If not, then airway control may be lost, with the risk of aspiration of gastric contents.

Full Stomach

Patients for elective surgery are usually starved for 6 hours to ensure an empty stomach, but can receive clear fluids for up to 1–2 hours before induction of anaesthesia. Nevertheless, every few years we have the unpleasant experience of dealing with elective patients who vomit undigested food at least 12 hours after a (probably enormous) meal in the absence of any intestinal abnormalities. In emergency surgery the 6-hour rule is unreliable, and all emergency patients should be treated as having a full stomach and so at risk of vomiting, regurgitation and aspiration.

Vomiting occurs at the induction of, and emergence from, anaesthesia. If gastric acid enters the lungs a pneumonitis results, which can be fatal. Aspiration can also occur following passive regurgitation of gastric contents up the oesophagus. This regurgitation is often described as ‘silent’ to distinguish it from active vomiting. Regurgitation is particularly likely at induction of anaesthesia, when drugs used may decrease the pressure in the lower oesophageal sphincter.

In emergency anaesthesia there is always a risk of aspiration, regardless of the period of starvation. Therefore, the trachea must be intubated as rapidly as possible after induction of

Box 23.3 Methods of facilitating tracheal intubation

- Patient awake
 - topical anaesthesia with fiberoptic intubation
- Patient anaesthetised
 - use of muscle relaxant suxamethonium
 - non-depolarising NMBD drugs (often a large dose to expedite its onset)
 - inhalational techniques
 - a range of sizes of tracheal tubes must be available
 - spare laryngoscopes must be available
 - ancillary intubation aids, bougies and stillettes must be available

Box 23.4 Management of tracheal intubation when risk of aspiration

- Empty stomach
 - from above by nasogastric tube
 - from below by drugs, e.g., metoclopramide
- Neutralise remaining stomach contents with antacids
 - H_2 blocking drugs to prevent further acid secretion
- Stop central nervous system induced vomiting, avoid opioids where possible
- Correct anaesthetic technique
 - 'rapid sequence induction'
 - preoxygenation, cricoid pressure, tracheal intubation

anaesthesia. The methods available are shown in Box 23.3. If preoperative assessment of the airway indicates no problems then tracheal intubation is performed under general anaesthesia. However, if a difficult airway is predicted then senior help must be called.

There are some basic requirements for tracheal intubation in emergency surgery:

skilled assistance must be present

the trolley must tip

the suction apparatus must work correctly and be left on

A plan of management of the patient who may have a full stomach and is at risk of aspiration is shown in Box 23.4.

Neither physical nor pharmacological methods should be relied on to empty the stomach completely. In some specialities such as obstetrics, an H_2 receptor blocking drug, ranitidine, is given routinely to decrease gastric acid secretion and 30 ml sodium citrate is used orally 15 minutes before induction of anaesthesia to increase the pH of the gastric contents. Opioids delay gastric emptying and increase the likelihood of vomiting.

The only reliable way to prevent regurgitation is to use the correct anaesthetic technique. This is called a rapid sequence induction (RSI), which sounds better than the old term – crash induction. It has three essential components: preoxygenation, cricoid pressure, tracheal intubation. The objective is to minimise the time interval between loss of protective airway reflexes and tracheal intubation with a cuffed endotracheal tube as the airway is unprotected in the event of regurgitation of gastric contents, without the use of bag and mask ventilation.

Preoxygenation

Before induction the patient must breathe 100 per cent oxygen for at least 3 minutes from a suitable breathing circuit. There should be no leaks and the flow rate of oxygen in the circuit should be high to prevent rebreathing. Air contains oxygen, nitrogen and minimal carbon dioxide. When the patient is breathing oxygen only, the lungs denitrogenate rapidly and after 3 minutes contain only oxygen and carbon dioxide. There is now a greater reservoir of oxygen in the lungs to utilise before hypoxia occurs. Ideally after preoxygenation the endtidal oxygen should be greater than 95 per cent.

Anaesthesia is then induced and cricoid pressure applied.

Cricoid Pressure

The cricoid cartilage is identified on the patient before anaesthesia is induced and the patient is warned that they might feel pressure on the neck as they go to sleep. The skilled assistant presses down on the cricoid cartilage as anaesthesia is induced and this pressure is applied continuously until the anaesthetist tells the assistant to stop (Figure 23.1).

The object of pressure on the cricoid cartilage is to compress the oesophagus between the cricoid cartilage and vertebral column. This prevents any material that has been regurgitated from the stomach into the oesophagus from passing into the pharynx.

Cricoid pressure is usually undertaken by firm, but gentle, pressure on the cartilage by the thumb and forefinger of the assistant. It is similar to the pressure exerted that causes mild pain when the thumb and forefinger are pressed onto the bridge of the nose. The

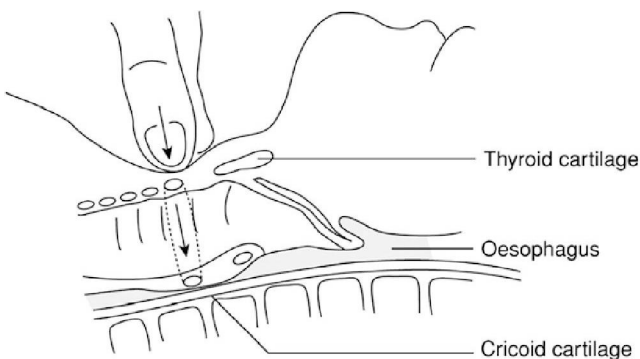


Figure 23.1 Application of cricoid pressure

Box 23.5 Major side effects of suxamethonium

- Muscle pain
- Bradycardia
- Raised intracranial pressure
- Raised intraocular pressure
- Raised intragastric pressure
- Allergic reactions
- Hyperkalaemia in burns, paraplegia, some myopathies
- Prolonged action in pseudocholinesterase deficiency
- Malignant hyperthermia

cricoid cartilage is used because it is easily identifiable, forms a complete tracheal ring and the trachea is not distorted when it is compressed.

The patient has now received preoxygenation, an induction agent and cricoid pressure. A neuromuscular blocking drug is given to facilitate intubation of the trachea.

Intubation

The neuromuscular blocking drug must act rapidly and have a short duration of action. The lungs are not ventilated during a rapid sequence induction; this will prevent accidental inflation of the stomach, which will further predispose the patient to regurgitation and vomiting. Gases can be forced into the oesophagus and stomach during manual ventilation of the lungs despite the application of cricoid pressure.

A drug with a rapid onset of action permits quick tracheal intubation. An agent with a short duration of action is valuable because in cases of failed intubation spontaneous respiration will return promptly. This allows other options to be considered (Chapter 4).

Suxamethonium has many side effects (Box 23.5) but is still used. More commonly, rocuronium is an alternative NMBD drug of rapid onset which is easily reversed with sugammadex.

Only when the trachea is intubated, the cuff inflated and the correct position of the tube confirmed, is the cricoid pressure released.

The concept of a 'modified RSI' is commonplace for more experienced anaesthetists whereby in some patients preoxygenation cricoid pressure will still be carried out but they may also receive gentle bag and mask ventilation and higher dose opioids. It should not be used until you are proficient at classical RSI.

The anaesthetic is maintained, usually with a volatile agent, oxygen, non-depolarising neuromuscular blocking drug and suitable analgesia. The reversal of the NMBD at the end of the procedure is undertaken with the anticholinesterase, neostigmine. Glycopyrrolate is given concomitantly to stop bradycardia occurring from the neostigmine. Sugammadex is increasingly used for reversal if rocuronium has been administered.

Rapid sequence induction has the major disadvantage of potential haemodynamic instability, as hypertension and tachycardia often occur following laryngoscopy and intubation. This is often more severe than in elective surgery when opioids are given at induction of anaesthesia.

Box 23.6 High risk factors for regurgitation

- Oesophageal disease
 - pouch, stricture
- Gastro-oesophageal sphincter abnormalities
 - hiatus hernia, obesity, drugs
- Gastric emptying delay
 - trauma, pyloric stenosis, gastric malignancy, opioids
 - patient predisposition, anxiety, pregnancy
 - recent food intake
 - diabetes (autonomic neuropathy)
- Abnormal bowel peristalsis
 - peritonitis, ileus – metabolic or drugs, bowel obstruction

Box 23.7 Signs of pulmonary aspiration

- None
- Oxygen desaturation
- Coughing
- Tachypnoea
- Unexplained tachycardia
- Wheeze
- Hypotension
- Pneumonitis
- Postoperative pulmonary disease

Other Indications for Rapid Sequence Induction

Every anaesthetic, not just emergency anaesthesia, should be considered from the point of view of unexpected vomiting or regurgitation. Some cases are at high risk, and rapid sequence induction should be considered carefully as an option in this group (Box 23.6).

Pulmonary Aspiration

Pulmonary aspiration may be obvious. The presence of lager and curry in the pharynx when the blade of the laryngoscope is inserted is a depressing sight. It may also be silent, presenting as a postoperative pulmonary complication. The signs of pulmonary aspiration are shown in Box 23.7.

Treatment requires the advice of a senior anaesthetist. The airway must be suctioned and oxygenation of the patient remains the priority. Bronchoscopy may be required to remove particulate matter. If the patient is not paralysed then, surgery permitting, he or she should

Box 23.8 Intensive Care Society levels of care**Ward Care**

- Patients whose needs can be met through normal ward care in an acute hospital.
- Patients who have recently been relocated from a higher level of care, whose needs can be met on an acute ward with additional advice and support from the critical care outreach team.
- Patients who can be managed on a ward but remain at risk of clinical deterioration

Level 1 Enhanced Care

- Patients requiring more detailed observations or interventions, including basic support for a single organ system and those 'stepping down' from higher levels of care.
- Patients requiring interventions to prevent further deterioration/rehabilitation needs which cannot be met on a normal ward.
- Patients who require ongoing interventions (other than routine follow up) from critical care outreach teams to intervene in deterioration or to support escalation of care.

Level 2 Critical Care

Patients requiring increased levels of observations or interventions (beyond level 1) including basic support for two or more organ systems and those 'stepping down' from higher levels of care.

Level 3 Critical Care

Patients needing advanced respiratory monitoring and support alone or requiring monitoring and support for two or more organ systems at an advanced level including multiple organ failures.

be allowed to wake up. If paralysed, intubation and ventilation must occur and oxygenation maintained.

Bronchospasm may be treated with salbutamol or aminophylline. Further treatment may include antibiotics, other bronchodilators and steroids. Aggressive early management is required.

Postoperative Care

Always plan the postoperative care of the patient. Inform the ward, high dependency unit or intensive care unit of your needs for the patient (Box 23.8).

HDU can be level 1 or 2. ICU can be level 2 or 3.

Conclusion

Anaesthesia for emergency surgery needs careful preoperative assessment, and adequate resuscitation must be undertaken before surgery. Impatient surgeons must be restrained. A rapid sequence induction of anaesthesia must follow the order of preoxygenation, cricoid pressure and intubation to prevent aspiration of gastric contents.

Emergency Laparotomy

The general principles of emergency surgery are dealt with in the previous chapter. However emergency laparotomy deserves its own chapter: it is a common procedure with historically often poor outcomes. These were multifactorial in origin, including poor patient status (often elderly and/or frail), delays in A&E or operating, procedures carried out by inexperienced staff and poor facilities for postoperative care (see Box 24.1 and Table 24.1). Mortality rates were approximately 15 per cent rising to 25 per cent in those over 80 years of age. In addition, long-term outcomes were often poor, with the associated disease burden and cost being enormous. Finally, it was recognised that there was great variability in both practice and outcomes amongst hospitals. As a result, these patients have been an area of intense focus for over ten years. You will learn a great deal about the management of sick patients from your involvement with these cases.

Emergency laparotomy refers to emergency surgery for major intrabdominal pathologies including bowel perforation, peritonitis (faeculent or purulent), ischaemia, uncontrolled haemorrhage, sepsis and anastomotic leak. The underlying condition includes bowel tumours, inflammatory bowel disease and complications from previous surgery. It excludes trauma laparotomies, other major vascular conditions, appendicectomy and cholecystectomy.

Patients are generally operated on rapidly but even in this short time frame there is time for improving patients' condition. Patients will often have markedly deranged physiology, including dehydration, sepsis and organ dysfunction (e.g., kidney injury) and a coagulopathy.

These patients require prompt management including

- Oxygen
- IV access, for fluid resuscitation (up to 30 mls/kg) and early antibiotics

Box 24.1 Specific preoperative problems in emergency laparotomy

- Fluid balance
- Electrolyte disorders
- Full stomach
- Sepsis
- Accompanying organ dysfunction (kidney, brain, liver)
- Airway assessment
- Calculation of risk and location of postoperative care

Table 24.1 Historical factors contributing to poor patient outcome in emergency laparotomy patients

Patient factors	Staff Factors	Organisational factors
Frail	Junior surgeon with little senior input	Delay with investigations e.g., radiology
Elderly	Junior anaesthetist with little senior input	Delay in surgery (no dedicated theatre)
Other comorbidities	Delay in assessment by frontline staff	Lack of ICU beds for postoperative care
Sepsis	Delay in advice, e.g., microbiology, frailty, delirium	Lack of access to appropriate monitoring, e.g., cardiac output
Dehydration	Delay in treating, e.g., antibiotics, fluids etc.	Sometimes accorded low priority (e.g., postponed to out of hours)
Organ impairment	Poor/absent risk assessment	Incomplete data collection/audit

- Urinary catheter
- Nasogastric tube if gastric distension is present
- Rapid assessment including arterial blood gases (ABGs) and imaging, risk scoring and assessment by care of the elderly if over 70 years old
- Early surgery within six hours, led by consultant surgeon and anaesthetist
- Goal directed fluid therapy
- Intensive care postoperatively especially if calculated mortality in 30 days exceeds 10 per cent

These cases are common in most hospitals and as a junior member of the team you will be involved in caring for these patients.

Preoperatively

Optimisation of these patients as above. Patients are often dehydrated, with electrolyte imbalances, with or without vasoplegia, with a metabolic acidosis, high lactate concentrations, and may be haemoconcentrated. Appropriate fluid resuscitation and the use of inotropes may be required (see Chapter 40). Patients usually require analgesia. In addition, coagulation should be checked (especially if patients were receiving anticoagulants before admission) and attempts made to normalise the clotting profile. If diabetes coexists, blood glucose control should also be addressed.

Calculation of perioperative risk and multidisciplinary involvement is crucial, including with the patient (if possible) and their next of kin to discuss any proposed ceiling of care, the surgical options, including damage limitation surgery and less minor surgery (such as defunctioning bowel surgery) if appropriate. Finally the option of not performing any surgery for patients must always be considered for patients *in extremis*, with little or no hope of

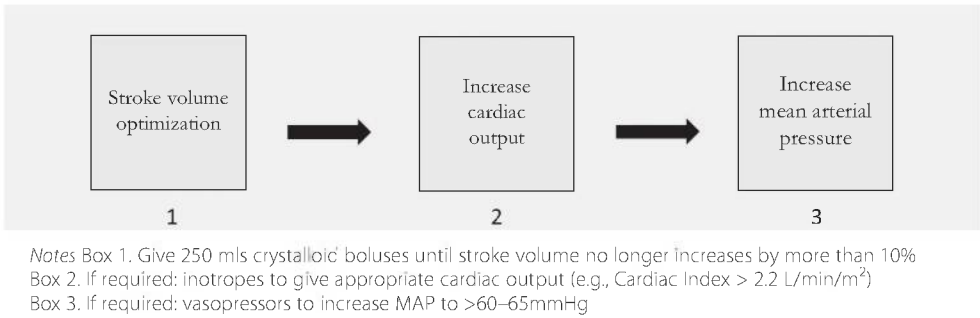


Figure 24.1 Fluid/inotrope management for emergency laparotomy

surviving or improving their overall health. For these patients appropriate end of life care must be instituted too.

Intraoperatively

Induction of anaesthesia requires full monitoring (often with arterial and central line). A rapid sequence induction is required to prevent pulmonary aspiration of gastric contents. In addition, these patients may have a low cardiac output and rapid injection of the usual dose of induction agent will very likely cause catastrophic falls in blood pressure. Therefore judicious dosing and the availability of vasoactive drugs must be available. Meticulous fluid management cannot be over-emphasised to prevent the hazards of hypovolaemia or hypervolaemia, both of which will jeopardise cellular oxygen delivery. Blood transfusion may be required. Planning pain management is crucial and these patients may be unsuitable for spinal or epidural anaesthesia (due to coagulopathy, sepsis and inability to withstand further reduction in vasomotor tone). In addition, non-steroidal anti-inflammatory drugs (NSAIDs) are usually contraindicated (risks of acute kidney injury – AKI) and analgesia may rely on rectus sheath block, opioids and other adjuvants (e.g., magnesium or ketamine). Close attention to microbiology (including repeat doses), prevention of hypothermia and lung protective strategies are also important. Fluid management is key and is no different to the management of any high-risk patient in theatre or ICU (Figure 24.1).

Postoperatively

Ideally all patients should receive a higher level of care than is available on a general ward, such as HDU or ICU. Major considerations include ongoing fluid management and analgesia. For some patients, tracheal extubation may be possible if the patient is physiologically stable (even if receiving inotropes), with relatively low oxygen requirements ($\text{FiO}_2 < 0.5$), satisfactory analgesia and with relatively normal pH, base excess and lactate levels. For others a short period of ventilation may be required until stability has resumed. Other issues to address include thromboprophylaxis and continued antibiotic cover. Wherever the patient is cared for, early detection of postoperative problems (both medical and surgical) is vital. Serious postoperative problems may also result in a decision to withdraw active treatment, again requiring appropriate end of life care.

As soon as is practical, patients need to be mobilised, and encouraged to drink. Nutrition is also essential, preferably enterally. If this is not possible for several days then parenteral nutrition may be required. When feasible, drains, tubes, urinary catheters should be removed. Input from other specialities is crucial too including frailty teams, physiotherapists, occupational therapists, dieticians and pharmacists.

Finally good data collection is required including complications, length of stay and preferably data collected several months later. Multidisciplinary morbidity and mortality meetings are essential to continually drive improvements in care. In addition, it must be recognised that some patient's perioperative risk is so high that they do not benefit from surgery – the NoLap group. These are difficult decisions, but important to address.

Case Study

An 84-year-old man presents with 6 days of abdominal pain. He is scheduled for a laparotomy with a diagnosis of perforated diverticular disease.

Preoperative Care

Preoperative preparation is the key to a successful outcome. The patient is likely to be dehydrated, haemoconcentrated with a very poor cardiac output and a metabolic acidosis. Time spent ensuring that the patient is as well resuscitated as possible is crucial. Apart from any co-morbidities, the major issues are ensuring adequacy of circulation and treatment of sepsis. The patient will need oxygen, arterial and central venous access, possibly nasogastric tube and urinary catheter. Appropriate antibiotics are required. Investigations should include haemoglobin, urea and electrolytes, coagulation and arterial blood gas analysis.

Severe acidosis (base excess greater than -10 mmol/l) with a high lactate value has a poor prognosis. Before theatre the patient should be cardiovascularly stable, with good perfusion, urine output of 0.5 ml/kg/h and not acidotic. A central venous pressure (CVP) of around 8 mmHg is ideal. Do not be pressurised by surgeons to anaesthetise a patient who is inadequately resuscitated. An hour or two in theatres optimising these patients before surgery improves outcome.

Perioperative Care

Induction Empty the stomach via the nasogastric tube. Rapid sequence induction.

Cardiovascular decompensation is common. An epidural can be hazardous and is rarely used due to sepsis, hypovolaemia and potential coagulopathy.

Maintenance Scrupulous attention to fluid balance – patient may need inotropes if blood pressure falls in spite of a high CVP (>10 mm Hg). Stroke volume optimisation as outlined in Table 24.2 may be helpful.

Postoperative Care

Supplemental oxygen and good pain control are crucial. Prolonged surgery, severe sepsis requiring inotropes and severe acidosis are indications for transfer to HDU/ICU for ventilation of the lungs. Often these patients deteriorate significantly immediately after surgery.

Anaesthesia for Minimally Invasive Surgery

Minimally invasive surgery (MIS) such as laparoscopic and robotic procedures are increasingly common in gynaecological surgery, general surgery and urology. Robotic surgery has also been used in orthopaedic, cardiothoracic and head and neck surgery but this chapter will focus on abdominopelvic procedures. Overall, there is more accurate surgical excision with minimal tissue damage.

Minimally invasive surgery began with laparoscopic surgery, but advances in technology have allowed improved optical resolution and three-dimensional imaging of the surgical field. In addition, telemanipulation paved the way for robotic-assisted surgery. Established MIS programmes have revolutionised care of patients, allowing reduced physiological upset and reduced length of hospital stay with quicker recovery, but initially there is a large increase in both operating time and surgical cost for these procedures.

The vast majority of MIS requires insufflation of carbon dioxide into the peritoneum to form a pneumoperitoneum. Carbon dioxide is used as the insufflating gas for reasons shown in Box 25.1.

There are three main anaesthetic considerations for MIS:

problems from gas insufflation and pneumoperitoneum

problems from positioning

trauma problems caused by Veress needle/trochar

Problems from Gas Insufflation

When carbon dioxide is insufflated to cause the pneumoperitoneum, physiological changes occur (Box 25.2), which are mainly cardiorespiratory in nature.

Box 25.1 Advantages of CO₂ use for pneumoperitoneum

- Cheap
- Readily available
- Non-toxic
- Does not support combustion
- More soluble in blood than air (20 ×)
- Buffered by formation of bicarbonate
- Readily excreted by the lungs

Box 25.2 Problems arising from gas insufflation

- | | |
|--|---|
| • Cardiovascular changes | arrhythmias
decreased venous return, increased afterload
decreased splanchnic blood flow
cardiac output – variable
blood pressure – variable
increased cerebral venous pressure (head down) |
| • Respiratory changes | decreased lung volumes, FRC
decreased pulmonary compliance
atelectasis
ventilation/perfusion abnormalities
lung barotrauma from high inflation pressures
hypercapnia due to absorbed CO ₂ |
| • Misplacement of the insufflating gas | |
| • Gas embolism | |
| • Hypothermia | |

Insufflation pressures of 10–15 mmHg are generally well tolerated, but pressures greater than 30 mmHg can result in profound haemodynamic responses. The pneumoperitoneum increases intra-abdominal and intrathoracic pressures. This decreases venous return and increases afterload, and so lowers cardiac output. Splanchnic perfusion is also reduced. In contrast, carbon dioxide absorption increases sympathetic activity to augment cardiac contractility and increase heart rate. During anaesthesia there is usually a satisfactory circulation with a normal or raised arterial blood pressure and a tachycardia. Problems arise, however, when haemorrhage occurs, as the usual compensatory cardiovascular responses may be inadequate.

The respiratory changes are related to diaphragmatic splinting and lung compression. This predisposes to basal atelectasis, increased intrapulmonary shunts, hypoxia and hypercarbia in spontaneously breathing patients. These changes are minimised by positive pressure ventilation and the addition of small amounts of positive end expiratory pressure (PEEP).

Cardiac arrhythmias may result from a low cardiac output in the presence of hypercarbia.

Inadvertent misplacement of the insufflating gas can cause subcutaneous emphysema, pneumomediastinum, pneumothorax and pneumopericardium. Although rare, we have seen all these complications, with the exception of a pneumopericardium.

Carbon dioxide gas embolism is a major complication, as a large embolus will cause outflow obstruction of the pulmonary artery. The diagnosis is made by the occurrence of sudden hypotension, hypoxia and a low expired carbon dioxide tension.

Hypothermia may occur in long procedures. A 0.3°C decrease in core temperature has been found for each 50 l of carbon dioxide insufflated.

Trauma by Veress Needle or Trochar

Major damage can occur (Box 25.3). Haemorrhage can result from the passage of the trochar or needle through the anterior abdominal wall. Tearing of adhesions from the expanding pneumoperitoneum will also cause bleeding. Traumatic puncture of the major intra-abdominal vessels has been reported. One author observed a large tear in the internal iliac artery, which was ultimately fatal. The raised intra-abdominal pressure may tamponade even a large vessel, and venous haemorrhage may not be obvious during the procedure, leading to a delay in a subsequent laparotomy.

Intestinal perforation can also occur. The bowel can be grazed, leading to peritonitis, abscess formation and sepsis. Puncture of the bladder, ureters and liver has been reported.

In summary, if an organ is in the peritoneal cavity, then it has been damaged during MIS.

Anaesthetic Problems Associated with MIS

There are several implications for the anaesthetist, aside from the cardiorespiratory changes outlined above. These are listed in Box 25.4.

Positioning of the patient is crucial. In general, the operating site is positioned uppermost so for an anterior resection the patient is head down and tilted to the right; the opposite applies for cholecystectomy. Great care must be taken during extremes of positioning to ensure that the patient is on a nonslip mattress with appropriate support and strapping to ensure the patient does not end up on the operating room floor.

The major cardiorespiratory consequences of MIS are altered by positioning. Head-up positioning will mitigate the diaphragmatic splinting but will exacerbate the effect on

Box 25.3 Complications from needle or trochar insertion

- Haemorrhage
- Intestinal perforation
- Other visceral trauma

Box 25.4 Anaesthetic problems of MIS

- Cardiorespiratory compromise
- Positioning of patient
- Nerve injury
- Conversion to laparotomy
- Lack of access to patient
- Aspiration of gastric contents
- Confusion from cerebral oedema
- Conjunctival oedema

reduced venous return. Conversely the Trendelenburg position will exacerbate diaphragmatic splinting but aid venous return.

It is logical that Trendelenburg position and a pneumoperitoneum will lead to an increased risk of passive regurgitation of gastric contents confirming the need for tracheal intubation. Procedures can be very prolonged and vigilance must be maintained. A steep head-down position increases cerebral venous pressure, intracranial pressure and intraocular pressure. Visual defects have been reported.

Nerve damage can occur: the common peroneal nerve, femoral nerve and the brachial plexus are at risk. A small number of patients proceed to laparotomy. The anaesthetist should be prepared for this possibility at the start of the procedure.

Postoperative pain can be decreased by infiltrating the wounds made by the trochar with local anaesthetic. Some anaesthetists use intrathecal opioids or abdominal nerve blocks to provide analgesia. Shoulder tip pain may occur from diaphragmatic irritation by the gas.

Many anaesthetic techniques have been used for laparoscopy. They are not performed under epidural and spinal anaesthesia because of the discomfort from peritoneal distension and respiratory stimulation. The safest and preferred technique is tracheal intubation and ventilation of the patient with careful monitoring of neuromuscular block. This allows abdominal wall relaxation and decreases the effects of diaphragmatic splinting on respiratory function. The risk of gastric aspiration is minimised – and, should a laparotomy ensue, you are prepared. Emergency MIS necessitates a rapid sequence induction technique. Adequate venous access is essential for laparoscopic surgery, as brisk haemorrhage can occur. The patient's arms are often strapped to their side and access to cannula and monitoring equipment can be very difficult intraoperatively, particularly during robotic surgery.

The popularity of robotic surgery may be related, in some instances, to surgeons' enthusiasm for big and expensive toys! Time spent on robotic docking and undocking is typically about 20 minutes for each phase. In an emergency situation, such as conversion to a laparotomy for haemorrhage, the anaesthetist should be prepared for a considerable delay between de-docking the robot and intra-abdominal access to control the haemorrhage.

Conclusion

MIS techniques have revolutionised surgery and made a massive contribution to the rapid recovery of patients. You must understand that although the surgery is minimally invasive, the cardiopulmonary and other physiological consequences of pneumoperitoneum are profound and may not be tolerated in patients with poor reserve. Also be aware of the potential for organ damage, haemorrhage and conversion to open surgery.

Anaesthesia for Abdominal Surgery

General Considerations

Minimally invasive surgery (MIS) techniques are used commonly in abdominal surgery, for example cholecystectomy and colectomy. The anaesthetic implications of this surgery are discussed in Chapter 25. However, open surgery is still required for elective abdominal surgery either from the outset or due to conversion from MIS. Emergency laparotomy is discussed in Chapter 24. Careful anaesthetic management of the patient is essential in all abdominal surgery, as major errors result in increased patient morbidity and even mortality.

In addition to routine preoperative assessment, particular attention should be given to the problems listed in Box 26.1. Fluid balance is often challenging. Whereas a patient presenting with emergency bowel obstruction may have up to 2–3 l of fluid sequestered in the bowel, in elective surgery, bowel preparation with enemas before surgery may cause a similar degree of dehydration, unless care is taken to provide adequate preoperative hydration.

A thorough assessment of the airway is mandatory, and patients at risk of regurgitation or aspiration (e.g., gastric outlet obstruction) should have a rapid sequence induction.

Some diseases of the gut, such as ulcerative colitis and Crohn's disease, are multisystem diseases in which the skin, joints, eyes, mouth and renal systems may be affected. These patients are often receiving steroid therapy, and appropriate steroid cover must be provided in the perioperative period. For most patients hydrocortisone 25 mg intravenously at induction followed by 100 mg intravenously/24 hours until oral therapy is restarted is sufficient. Occasionally, it is necessary to give more hydrocortisone to maintain immune suppression during an acute illness. For example, a patient receiving 60 mg prednisolone/day should receive an equivalent dose of hydrocortisone ($60 \text{ mg} \times 4 = 240 \text{ mg}$). The perioperative problems of abdominal surgery are shown in Box 26.1.

Box 26.1 Perioperative considerations in abdominal surgery

- Rapid sequence induction of anaesthesia may be required
- Venous and sometimes arterial access
- Muscular relaxation
- Vagal responses to surgery
- Infection
- Position of the patient
- Body temperature control
- Adjunct regional analgesia
- Haemorrhage + fluid therapy

Most abdominal surgery requires adequate muscular relaxation. Sudden traction of viscera can stimulate vagally mediated reflexes and result in a bradycardia. Bowel inflammation, perforation and obstruction can lead to septicaemia from a 'septic shower' and antibiotics such as gentamicin, cefuroxime and metronidazole are often given pre- and intraoperatively. Gentamicin, an aminoglycoside antibiotic, theoretically potentiates the action of competitive neuromuscular blocking drugs. It is obviously a rare occurrence, as the authors have not encountered this problem.

Patients in the Lloyd Davies position can suffer nerve damage to the legs, and these should be padded appropriately. The common peroneal nerve at the top of the fibula is particularly at risk, and foot drop may occur postoperatively. Access to the airway and the venous cannula is often difficult.

Certain drugs affect bowel motility. Opioids increase circular smooth muscle contractility of the gut and hence bowel tone, decreasing propulsive activity. Nitrous oxide is rarely used as it distends gas-filled cavities such as the bowel. Neostigmine increases gastrointestinal motility, which may threaten an intestinal anastomosis. There is little evidence, however, that the routine use of neostigmine increases the rate of anastomotic leaks after major abdominal surgery. Heat conservation in abdominal surgical patients is important. The exposure of the viscera to air at room temperature exacerbates heat lost by radiation and convection.

Temperature losses $> 0.5^{\circ}\text{C}/\text{h}$ have been found, particularly when peritoneal lavage is used. Heat loss should be prevented with hot-air warming blankets, heat and moisture filters in the circuit and the use of warming devices for intravenous fluids.

Regional anaesthetic techniques, such as epidural anaesthesia, are often used to provide intraoperative and postoperative analgesia. Major bowel surgery cannot be carried out with these techniques alone unless a block above T4 is achieved. Regional anaesthesia is commonly used to supplement general anaesthesia with controlled ventilation for major surgery. The integrity of the bowel anastomosis is critically important in abdominal surgery. An adequate circulating blood volume and arterial pressure must be maintained to ensure that blood flow to the gut is not compromised.

Particular postoperative problems are shown in Box 24.2.

Pain after laparotomy can result in hypoventilation, lung collapse and infection. Good postoperative analgesia is important, and regional anaesthesia is often used. Patient-controlled analgesia is an alternative technique.

Careful fluid balance is important, as an ileus postoperatively can cause large fluid losses that are not recognised. Historically urine output ($> 0.5 \text{ ml/kg/h}$) was chased with intravenous fluids, but the stress response to surgery causes oliguria and attention is now more focused on central venous, arterial pressure and stroke volume optimisation which will promote adequate perfusion.

Box 26.2 Specific postoperative problems in abdominal surgery

- Analgesia
- Fluid balance
- Oxygen therapy
- High-dependency nursing care

Box 26.3 Anaesthetic problems of anal surgery

- Depth of anaesthesia
- Intraoperative analgesia
- Position of patient
- Arrhythmias
- Laryngospasm
- Postoperative analgesia

Intrapulmonary shunts and hypoventilation after abdominal surgery are common and may persist for up to 72 hours after surgery. Postoperative oxygen therapy may be needed during this time.

Appropriate nursing care must be provided after major abdominal surgery. This usually necessitates admission to a high dependency unit or intensive care unit.

Anal Surgery

Operations in the anal region such as fistulae, drainage of perianal abscess, excision of pilonidal sinus, haemorrhoidectomy and lateral sphincterotomy can cause anaesthetic difficulties.

Profound anaesthesia is necessary, but the patient must awaken rapidly after surgery and be pain-free. A regional technique applied at the end of surgery, such as local anaesthetic infiltration or caudal anaesthesia, is helpful.

The anaesthetic problems of anal surgery are shown in Box 26.3.

The patient is usually placed in the lithotomy position; access to the venous cannula and airway may be difficult. If the depth of general anaesthesia is inadequate, arrhythmias, especially bradycardia, and laryngospasm may occur with the application of a painful stimulus. The anaesthetic therefore requires skill and simplicity. Anaesthesia is conducted with a suitable induction agent, opioid, oxygen and a volatile agent. Atropine and a neuromuscular blocking drug (NMBD) must be available.

It is embarrassing for a previously smooth anaesthetic to degenerate into a noisy shambles as the patient develops laryngospasm when the haemorrhoid is clamped firmly by the surgeon. The management of laryngospasm is discussed in Chapter 19.

Pilonidal surgery requires the patient in the lateral position or occasionally in the prone position (see Chapter 30).

Conclusion

Major abdominal surgery is difficult. The patients are often ill, with pre-existing fluid and electrolyte problems. Careful preoperative assessment and resuscitation, and high-quality postoperative care, are essential.

A combination of general and regional anaesthesia is often appropriate. Beware anal surgery – a small orifice that causes big problems (anaesthetically, of course).

Anaesthesia for Gynaecological Surgery

Gynaecological surgery is undertaken for diagnostic and therapeutic reasons. The trainee anaesthetist is often introduced to anaesthesia by means of supervised teaching on routine gynaecology lists. Much elective and emergency gynaecological surgery is undertaken via minimally invasive techniques (Chapter 25). Gynaecological patients are common on emergency lists.

Ectopic Pregnancy

Ectopic pregnancy is sometimes a life-threatening emergency. Whilst less common due to earlier diagnosis, death from haemorrhage can still occur. These patients must not be delayed for anaesthetic reasons. The relevant anaesthetic considerations are shown in Box 27.1.

Patients are often very upset; be kind. There may be considerable blood loss, and full resuscitation should occur before induction of anaesthesia. Adequate blood must be available, but occasionally it is necessary to start surgery without this facility to save life. Insert a wide-bore intravenous cannula before induction; do not rely on a cannula placed by a gynaecologist.

A rapid sequence induction technique is used to avoid gastric aspiration. The surgical procedure may be done by a laparotomy, or by a laparoscopic technique. Appropriate postoperative analgesia should be prescribed.

Case Study

A 32-year-old woman is pale, sweaty, with lower abdominal pain. Her heart rate is 120/min and BP 75/40. The diagnosis is ruptured ectopic pregnancy. She presents for an emergency laparotomy.

Box 27.1 Anaesthetic considerations in ectopic pregnancy

- Patient empathy
- Emergency anaesthesia
- Haemorrhage
- Pregnancy
- Surgical technique – laparotomy or laparoscopy
- Postoperative analgesia

Preoperative Care

Oxygen, large-bore venous cannula, cross-match four units of blood, rapid, warmed intravenous fluid until blood is available. May require central venous pressure (CVP) monitoring and a urinary catheter.

Perioperative Care

Induction. Rapid sequence induction and intubation. Use cardiovascular stable drugs. Arterial cannula may be required.

Maintenance. Ensure BP, heart rate and temperature are maintained in normal range.

Postoperative Care

Will require close monitoring, including CVP and urine output, to check for fluid status. If massive blood transfusion, will require check haemoglobin and clotting screen postoperatively. Check chest X-ray for CVP line position, if used. Check arterial blood gases (ABGs) for acidosis and lactate. Pain control is essential, such as patient controlled analgesia (PCA). Will usually require oxygen for 12 hours.

Evacuation of Retained Products of Conception or Surgical Management of Miscarriage

This operation is very common, and the anaesthetic considerations are shown in Box 27.2. Again a sympathetic approach to the patient is essential. A miscarriage is a huge and tragic event for a family. This is a common operation and is not an emergency procedure. In the absence of haemorrhage it should be undertaken during routine operating time. The risks of the procedure are haemorrhage, infection and uterine perforation. Oxytocic drugs are used to contract the uterus. Syntocinon is commonly used as a bolus injection and occasionally causes hypotension. Ergometrine contracts smooth muscle and can provoke vomiting. Mostly these operations are uncomplicated but be wary. Occasionally, excessive bleeding occurs which can be as much as 2–3 l. It is an overconfident anaesthetist who does any emergency without a wide-bore venous cannula!

Box 27.2 Anaesthetic considerations for ERPC/SMM

- Patient empathy
- Timing of surgery
- Position of patient
- Pregnancy
- Haemorrhage
- Oxytocic drugs
- Infection
- Type of anaesthesia
 - regional or general
 - need for tracheal intubation

Regional anaesthesia can be used for this procedure (epidural, spinal) and a level of analgesia to T10 is required, but usually the surgery is carried out under general anaesthesia. There are two special considerations. The first relates to the pregnant patient and the full stomach. If the procedure is not an emergency, the patient is not suffering from any specific symptoms of pregnancy, such as heartburn, and the patient is less than 16 weeks pregnant, then tracheal intubation is unnecessary. If the patient is more than 16 weeks pregnant, a rapid sequence induction and tracheal intubation is recommended.

The second is the use of volatile anaesthetic agents that relax the uterus. This increases blood loss and the risk of perforation of the uterus. Therefore, some anaesthetists will not use volatile agents, preferring instead a total intravenous anaesthesia (TIVA) technique.

Laparotomy

General anaesthesia for operations on the uterus and the ovaries is similar to that described in abdominal anaesthesia (Chapter 26).

Regional anaesthesia is an excellent adjunct for general anaesthesia for gynaecological surgery, with the benefit of good postoperative analgesia. The innervation of the uterus is up to T10. If manipulation of the bowel occurs, or if there is haemorrhage in the paracolic gutters, the patient may experience discomfort. An extension of neural blockade to T4 (as for a Caesarean section) is then needed to relieve pain.

Hysteroscopy

In this procedure clear irrigating fluid is used to expand the uterus and allow endoscopic visualisation of the contents. This technique is similar to that used for resection of prostates in urological surgery. Although the risks are usually slight, acute water intoxication can occur with this procedure (see Box 28.4).

Major Gynaecological Surgery

Hysterectomy for benign disease and more major surgery for gynaecological malignancies can be performed by MIS or open surgery. For open surgery, prepare in the same manner as you would for a laparotomy (Chapter 25), but beware that for malignancies, major surgery may involve bowel and bladder. Collateral injury to major blood vessels, ureters and other structures have all been described. Ensure you have blood cross-matched as pelvic bleeding can be catastrophic and difficult to control.

Conclusion

You will undertake a lot of anaesthesia for gynaecological surgery in the early months of your career. Always assume that the gynaecologists have no knowledge of anything that occurs outside the pelvis, preoperative assessment must be meticulous and do not underestimate their ability to cause severe blood loss.

Anaesthesia for Urological Surgery

Urological surgical lists provide supervised experience in anaesthetising often elderly patients with medical problems. They are useful for learning basic regional techniques such as spinal anaesthesia. Always remember that instrumentation or surgery of the urinary tract may cause bacteremia and urosepsis perioperatively so generally antibiotics (e.g., gentamicin) should be given before the start of surgery.

Transurethral Resection of the Prostate

This operation is the conventional procedure for benign prostatic hyperplasia and involves resection of the prostate by a modified cystoscope, which cuts tissue and coagulates blood vessels. The procedure is facilitated by means of irrigating fluid that flows through the cystoscope. This fluid washes blood away from the cut prostatic tissue so that the operative site can be seen. Further resection occurs and any bleeding venous sinuses are coagulated. The requirements of the irrigating fluid are shown in Box 28.1.

The current from the diathermy must not be spread to the bladder wall through the irrigating fluid. The fluid must be non-toxic, especially if absorbed through the open venous sinuses of the prostate. The usual solution used is glycine 1.5 per cent, which is slightly hypotonic (2.1 per cent is isotonic).

Irrigation is performed under hydrostatic pressure during prostatic resection, and some intravenous absorption of the glycine will take place through the prostatic venous sinuses. The amount of irrigating fluid absorbed depends on several factors (Box 28.2).

Box 28.1 Requirements for urological irrigating fluid

- Prevents dispersal of electrical current
- Clear for visibility
- Sterile
- Non-toxic locally
- Non-toxic systemically
- Isothermic
- Isotonic
- Non-haemolytic
- Inexpensive

Box 28.2 Factors influencing the absorption of glycine

- Hydrostatic pressure of the irrigating fluid
- Number and size of the venous sinuses opened
- Duration of surgery
- Venous pressure at the irrigant–blood interface

Box 28.3 Anaesthetic problems for TURP

- Elderly population
- Concurrent diseases
- Dilutional hyponatraemia and overhydration (TURP syndrome)
- Haemolysis
- Haemorrhage
- Infection
- Patient position
- Hypothermia
- Perforation of bladder
- Erection
- Adductor spasm
- Burns and explosions
- Postoperative clot retention

The height of the glycine should be less than 70 cm above the patient. Symptoms of glycine absorption may take as little as 15 minutes to appear, and up to 2 l of fluid can be absorbed. Usually surgery is restricted to a duration of 1 hour only.

Anaesthetic considerations for Transurethral Resection of the Prostate (TURP) are shown in Box 28.3.

Elderly men often have moderate medical problems, which must be assessed and treated preoperatively. If prostatic obstruction is chronic, renal impairment may be present.

Transurethral Resection of the Prostate Syndrome

The absorption intravenously of the irrigating fluid, if severe, causes iatrogenic water intoxication – the TURP syndrome. This can present in a number of ways and is more easily detected in an awake patient (regional anaesthesia). Symptoms and signs of the TURP syndrome are shown in Box 28.4. An identical syndrome can be seen in women undergoing transcervical resection in the uterus, again secondary to systemic absorption of the irrigating fluid.

Signs of cerebral irritation are usually seen first, and vomiting is a consistent feature. Under general anaesthesia ECG changes, such as a wide QRS complex, T-wave inversion, and rarely ventricular tachycardia and asystole, may be the only signs. If water intoxication is suspected, the blood tests shown in Box 28.5 should be done immediately.

The most important findings are a low plasma sodium concentration, low osmolality and low haemoglobin concentration. A sodium concentration <120 mmol/l is associated

Box 28.4 Symptoms and signs of acute water intoxication (TURP syndrome)

- Agitation
- Restlessness
- Confusion
- Vomiting
- Blurred vision
- Transient blindness
- Coma
- Convulsions
- Unexplained bradycardia
- Unexplained hypotension
- Unexplained hypertension
- Pulmonary oedema
- ECG changes
- Asystole

Box 28.5 Blood tests in suspected TURP syndrome

- Haemoglobin/haematocrit
- Serum osmolality
- Plasma sodium
- Plasma potassium
- Plasma glycine
- Plasma ammonia

with significant symptoms and signs. The plasma ammonia and glycine values will not be immediately available, but will confirm the absorption of the glycine.

Treatment should be aimed at prevention and then management of the syndrome (Box 28.6). Treatment of acute intoxication is undertaken rapidly; the prompt reversal of chronic water intoxication can result in cerebral pontine myelosis.

The TURP syndrome is a medical emergency and needs experienced anaesthetic help. Diuretic therapy is the mainstay of treatment and frusemide is the agent of choice; 0.9% sodium chloride or even hypertonic saline should be given judiciously to increase the plasma sodium concentration.

Other Anaesthetic Problems

Haemolysis presents in a similar way to a transfusion reaction. The patient may complain of weakness, rigours and chest pain, and become hypertensive. Haemoglobinaemia, haemoglobinuria and anaemia may occur, with acute tubular necrosis. Treatment should be directed towards obtaining a diuresis and specific correction of the haematological and biochemical abnormalities.

Haemorrhage is not uncommon, and blood loss is difficult to assess since the blood is diluted with irrigating fluid. The usual methods of estimating blood loss are inappropriate. Careful assessment of the circulation by conventional means is used. If methods of

Box 28.6 Management of water intoxication in TURP syndrome

- Prevention
 - correct intravenous fluid of choice (avoid 5 per cent glucose, glucose/saline solutions)
 - short duration of surgery by competent surgeon
- Treatment
 - stop surgery if possible
 - oxygen
 - CVP measurement
 - diuresis
 - intravenous sodium solutions
 - circulatory support
 - symptom control
 - may require ventilation

estimating the haemoglobin concentration of the irrigating fluid are available, then the blood loss can be calculated.

The patient is in the lithotomy position, which assists venous return. When the patient's legs are placed horizontally at the end of surgery, especially when regional techniques are used, the arterial pressure often declines as a result of the decreased venous return.

Irrigating fluids during prolonged surgery cause hypothermia. Occasionally, perforation of the bladder can occur.

Erection, which usually occurs when regional anaesthesia is used, prevents instrumentation of the penis and surgery is not possible. Ketamine in small incremental doses of 5–10 mg intravenously is reputed to help with this irritating and embarrassing problem.

If the obturator nerve is stimulated accidentally by the surgeon, adductor spasm occurs. Sudden closure of the thighs commands the attention of the surgeon.

There is always a slight risk of burns and explosions, since the diathermy carries high-frequency current at a power of up to 400 W with a voltage of 2,000 V.

If clot retention occurs postoperatively, the urinary catheter will block. The irrigating fluid must be turned off until the clot is removed by flushing the catheter and bladder. If the irrigating fluid is kept running, the bladder will fill and the irrigating fluid will be absorbed through the prostatic venous plexus. This is painful and dangerous, with the risk of TURP syndrome.

The surgical procedure is not usually painful and, after regional anaesthesia, little further pain relief is needed. The choices of anaesthesia for TURP are shown in Box 28.7.

Regional anaesthesia must reach the level of T10 to prevent pain from bladder distension. General and regional anaesthesia are sometimes combined.

The advantages and disadvantages of regional anaesthesia are shown in Box 28.8. The advantages and disadvantages of general anaesthesia are shown in Box 28.9.

Box 28.7 Anaesthesia for TURP

- Regional anaesthesia ($\pm$ sedation)
 - spinal or epidural (a single shot spinal will usually suffice)
- General anaesthesia
 - spontaneous ventilation
 - controlled ventilation

Box 28.8 Advantages and disadvantages of regional anaesthesia for TURP

- Advantages
 - avoids complications of general anaesthesia
 - better postoperative analgesia
 - early recognition of TURP syndrome
 - reduced incidence of deep vein thrombosis
 - earlier mobilisation
 - less bleeding intraoperatively
 - better operative field
- Disadvantages
 - less control of arterial pressure
 - headaches
 - difficult to position elderly patient for block
 - patient preference for unconsciousness

Box 28.9 Advantages and disadvantages of general anaesthesia for TURP

- Advantages
 - often faster
 - patient preference
 - surgeon preference
 - better control of arterial pressure
 - avoids complications of regional anaesthesia
- Disadvantages
 - slower recovery period
 - postoperative analgesia less good
 - slower mobilisation
 - slower recognition of TURP syndrome
 - risk of general anaesthetic complications

Case Study

A 72-year-old man presents for TURP with a two-week history of chronic retention with overflow. He also has atrial fibrillation (AF) at a rate of 120/min and takes aspirin, and ramipril for hypertension.

Preoperative Care

Patient may have some renal impairment (and hyperkalaemia) from earlier ureteric obstruction with anaemia. The AF rate should be controlled to approximately 80–90/minutes preoperatively. Consider spinal anaesthesia. Continue aspirin.

Perioperative Care

Induction. Choice of regional or general anaesthesia – see Boxes 28.8 and 28.9.

Maintenance. Ensure blood pressure is maintained to prevent further deterioration in renal function. Avoid nephrotoxic drugs (gentamicin/NSAIDs). Fluid replacement (including blood if required) is essential, particularly when the legs are lowered, as hypotension can occur.

Postoperative Care

Watch for haemorrhage and TURP syndrome. The latter can complicate prolonged surgery when large amounts of hypotonic solution are absorbed resulting in fluid overload and hyponatraemia, which leads to oedema (cerebral and pulmonary) (Box 28.4). Check urea, electrolytes and haemoglobin postoperatively (Box 28.5).

Recent advances in the treatment of benign prostatic hyperplasia include using a bipolar current with 0.9% saline irrigation (which can still be absorbed in large volumes to cause hyperchloraemic alkalosis) and other techniques such as laser, steam or various implants.

Cystoscopic Procedures

Cystoscopy can be done with flexible or rigid cystoscopes on an inpatient or outpatient list, under either general or local anaesthesia. Rigid cystoscopy is usually performed under general anaesthesia. The surgical requirement for resection, or biopsy, of the bladder wall is that the patient does not cough or strain unexpectedly, and that respiration is not forced (a smooth anaesthetic with a perfect airway). Otherwise, the bowel will move the bladder wall and there is a risk of perforation. A laparotomy will be required to repair the bladder.

Circumcision

Circumcision, whether in a child or an adult, is a painful operation, and good postoperative analgesia must be provided. The most common methods are either a caudal anaesthetic, which may result in leg weakness for several hours, or a penile nerve block. For the latter, local anaesthetic is injected in the midline below the symphysis pubis, with the risk of intravascular injection. Never use local anaesthetics containing adrenaline for a penile nerve block.

Operations on Testicles

Torsion of the testes is a surgical emergency, and appropriate precautions must be undertaken (see Chapter 23). The operation is usually conducted under general anaesthesia. If regional anaesthesia is used, neuronal blockade to the level of T9 is required.

Box 28.10 Specific Considerations in renal surgery

- Position of patient
- Difficult access to intravenous cannulae
- Muscle relaxation
- Haemorrhage
- Pneumothorax
- Postoperative analgesia

Renal Surgery

Specific problems of renal surgery are shown in Box 28.10. The patient may be supine or in a lateral, jack-knife position. Good muscular relaxation is a surgical requirement. Intraoperative haemorrhage may be considerable. The risk of a pneumothorax should not be underestimated (see Chapter 18). Good postoperative analgesia is essential, and epidural analgesia is often used. A combination of general anaesthesia and regional anaesthesia (epidural) is particularly appropriate for renal surgery.

Major Surgery for Prostate and Bladder Malignancy

Total prostatectomy or cystectomy (or both) are performed usually via minimally invasive surgery (MIS) either laparoscopically or more commonly robotically. The considerations for these procedures are considered in Chapter 25. The surgery can be prolonged, in the head-down position and the risks of cerebral and conjunctival oedema need to be considered. In addition, for cystectomy there is risk of volume overload and hyperkalemia if there is a significant delay between ureter clamping prior to their reimplantation into bowel or a neobladder.

Conclusion

Urological surgical lists are often unpopular with trainees, as anaesthesia for these patients can be challenging. Patients are usually male, elderly, with medical problems, and the surgery has some specific complications. Remember any fluid used for irrigation may be absorbed in significant volumes. Be on the lookout for reduced renal function and urosepsis.

Careful preoperative assessment is essential and regional anaesthesia is often appropriate. One author spent many happy years helping relieve obstructions in old men.

Anaesthesia for Maxillofacial and ENT Surgery

The problems of anaesthetising for surgical procedures in and near the airway are common to both maxillofacial and ENT surgery.

Shared Airway

A patent, secure airway is essential for safe anaesthetic practice. If possible, the tracheal tube or supraglottic airway device (SAD) should not protrude into the surgical field. Conventional tracheal tubes or laryngeal mask airway (LMAs) are used less frequently; often preformed tracheal tubes (such as RAE tube), nasal tubes and reinforced LMAs are used. Immediate access to the airway is lost once the patient is draped and surgery has started. The anaesthetic circuit is often long (and occasionally bulky), as the anaesthetic machine is placed at the feet of the patient. Two major problems may arise.

- The weight of the circuit can pull out or kink the tracheal tube: care must be taken to ensure that the circuit is supported to avoid drag.
- The surgeon may inadvertently obstruct the airway by kinking tracheal tube or moving the LMA when operating.

If the airway is lost, surgery must be stopped and appropriate adjustments made. Most surgeons understand the problems of the shared airway and are cooperative. However, one author had the alarming experience of the surgeon suddenly handing him the tracheal tube because it was interfering with the surgery.

Venous access is also restricted, and extension tubing on an intravenous cannula is essential.

Dental Anaesthesia

Anaesthesia in the dental chair has a justifiable reputation as one of the major sporting events in anaesthetic practice and is now almost obsolete. Anaesthetic techniques and considerations used are listed in Box 29.1 and Box 29.2.

Some surgeons prefer a dry mouth as it makes surgery easier, so an anticholinergic drug is used; it also protects against a bradycardia that often occurs during surgery. An intravenous induction is used if there are no difficulties with the airway. Control of the airway is obtained with a nasotracheal tube, and if throat packs are inserted before surgery (to collect blood and debris) you must ensure that they are removed at the end of surgery. It is easy to inadvertently leave the throat packs in situ and obstruction of the airway can occur. One author always ties one end of the pack to the nasotracheal tube, or circuit, to act as an obvious reminder.

Box 29.1 Anaesthetic techniques for dental surgery

- Local anaesthesia
- Local anaesthesia and sedation
- Sedation
 - intravenous
 - inhalational
- General anaesthesia
- General anaesthesia and local anaesthesia

Box 29.2 Considerations for general anaesthesia in dental surgery

- Antisialagogue
- Method of induction
- Type of tracheal tube
- Throat packs
- Surgical infiltration of local anaesthetic with felypressin
- Patient position – usually supine
- Mouth props
- Maintenance of anaesthesia
- Haemorrhage
- Arrhythmias
- Postoperative analgesia
- Laryngospasm
- Antibiotics
- Decrease in local swelling with steroids

Complications during and after dental surgery are common. Severe haemorrhage is fortunately rare after dental surgery, but if there is any doubt about the adequacy of haemostasis then the patient must be kept in hospital under close observation. Arrhythmias are common (30% of patients) and can continue in the postoperative period. Oedema can be minimised by the use of steroids before surgery. Extubation of the trachea can be undertaken under light or deep anaesthesia. Under deep anaesthesia the patient is less likely to develop laryngospasm, but is more likely to aspirate vomit, blood or debris. Under light anaesthesia the patient has adequate protective reflexes, but is more prone to laryngospasm and coughing (which will increase bleeding).

Emergency Dental Anaesthesia

Emergency dental anaesthesia should not be underestimated; get help from senior anaesthetists. The principal problem in a patient with a dental abscess or mandibular fracture is difficulty in opening the mouth, and hence with intubation. Distorted facial anatomy compounds the problem. Awake tracheal intubation is often necessary in these patients.

Vigorous antibiotic therapy may decrease the infection, and the urgency of the surgery should be discussed with the surgeon. Only rarely is it a life-threatening emergency.

If the airway is not safe postoperatively, the patient should be managed in the HDU.

Other Maxillofacial Surgeries

These include operations for temporomandibular joint dysfunction, orthognathic surgeries and major surgery for head and neck cancers. This last group forms a most challenging group. The airway may be difficult to manage because of tumour involvement or radiotherapy. Patients may have a history of heavy alcohol and/or nicotine use and also have cachexia and weight loss. The surgery may be prolonged particularly if there is a large reconstruction (such as a rotational flap or a free flap) and these patients require attention to blood loss and preservation of temperature. In addition if a free flap is used, access will be required to the donor site (such as the forearm). Patients require ICU postoperatively and many will have a tracheostomy sited intraoperatively.

Case Study

A 23-year-old man with type 1 diabetes presents with a massive dental abscess. He has severe trismus, a blood glucose of 21 mmol/l and ketonuria.

Preoperative Care

Control the severe hyperglycaemia with a glucose–insulin–potassium infusion and correct dehydration. Check circulating glucose and potassium.

Perioperative Care

Induction. Awake tracheal intubation, awake or sedated (IV induction with blind nasal intubation is no longer recommended)

Avoid oral intubation if possible.

Maintenance fluids, antibiotics, aim for blood glucose <10 mmol/l.

Postoperative Care

Maintain glucose–insulin–potassium until oral intake resumed and then revert to usual insulin regimen. May require additional insulin until infection resolved.

Box 29.3 Anaesthetic considerations for tonsillectomy

- Child – problems with parents
- Premedication (EMLA and sometimes sedation)
- Induction of anaesthesia
- Type of tracheal tube
- Use of Boyle Davis gag
- Postoperative analgesia
- Laryngospasm
- Postoperative haemorrhage

Box 29.4 Anaesthetic problems in the bleeding tonsil

- Senior help essential
- Occult haemorrhage
- Full stomach with blood
- Patient often hypovolaemic
- Resuscitation
- Repeated anaesthesia
- Method of induction
 - inhalation
 - intravenous
- Secure airway
- Postoperative care

ENT Anaesthesia

The trainee is frequently introduced to anaesthesia for children on ENT lists. The anaesthetic problems of a child undergoing tonsillectomy and adenoidectomy are shown in Box 29.3.

A child with anxious parents needs special support. The parents are often present in the anaesthetic room during the induction of anaesthesia, which is undertaken either by the inhalational or the intravenous route. Sedative premedication is helpful. Oral midazolam syrup and topical EMLA cream are used commonly. A preformed tracheal tube (commonly a RAE tube) minimises, but does not exclude, the risk of the Boyle–Davis gag kinking and obstructing the tube. Analgesia is given intravenously during surgery to decrease pain on emergence from anaesthesia. As in maxillofacial surgery, extubation can be carried out with the patient lightly or deeply anaesthetised. Laryngospasm is again a hazard. Postoperative haemorrhage is always a potential problem (see section on The Bleeding Tonsil).

The Bleeding Tonsil

Haemorrhage after a tonsillectomy is a serious complication and senior assistance must be sought. The anaesthetic problems are summarised in Box 29.4.

There may not be much visible evidence of haemorrhage; often all the blood is swallowed. If this occurs the stomach can contain a large amount of coagulated blood. A nasogastric tube will not remove this blood and aggravates the traumatised pharynx; it should not be used. The patient may be hypovolaemic, and full, appropriate resuscitation must occur before surgery.

There is debate about the method of facilitating tracheal intubation. An inhalational induction, with the patient head-down in the left lateral position, maintains control of the airway at all times and any bleeding trickles out of the mouth under gravity. A rapid sequence induction may be unsafe if there is blood, or a haematoma, in the pharynx, since the airway may become obstructed before the trachea is intubated. Although we prefer the former method, we have not seen serious sequelae from a rapid sequence induction.

Box 29.5 Anaesthetic considerations for middle ear surgery

- Avoidance of preoperative tachycardia
- Shared airway
- Prolonged surgery
- Hypotensive anaesthesia
- Postoperative vomiting
- Postoperative analgesia

Box 29.6 Techniques for induced hypotension

- No obstruction to venous outflow
- No coughing or straining (increases venous pressure)
- Head-up tilt
- Use of intermittent positive pressure ventilation
- Intra-arterial monitoring essential
- Specific hypotensive drugs
 - labetalol
 - nitroglycerine

A patient who has received two anaesthetics in a short time and required resuscitation should be managed in the HDU or even ICU postoperatively.

Ear Surgery

Minor endoscopic procedures on the ear are conducted with the patient breathing spontaneously through a well-secured and correctly positioned SAD. More complex middle ear or mastoid operations have special problems (Box 29.5).

The patient should arrive in the anaesthetic room sedated and with a normal heart rate. The avoidance of a tachycardia makes hypotensive anaesthesia easier to achieve. Nitrous oxide diffuses into air-filled spaces and in some surgical procedures causes difficulties, so many anaesthetists avoid nitrous oxide for middle ear surgery. Postoperative vomiting can be severe, and potent antiemetics are essential.

Induced hypotension is often used in these patients to decrease haemorrhage and improve the surgical field under the operating microscope. It is only suitable for patients without major cardiovascular disease, and mean arterial pressures less than 60 mmHg are unnecessary. The techniques available are shown in Box 29.6.

Another common operation is endoscopic sinus surgery and similar considerations apply in terms of hypotensive anaesthesia. In addition, the nose is often 'prepared' to reduce intraoperative bleeding. Cocaine is sometimes used but beware as it has significant risk of cardiovascular nervous system (CVS) and central nervous system (CNS) excitation. Many now prefer a safer combination of other local anaesthetics, mixed with a vasoconstrictor, for example lidocaine and phenylephrine.

Conclusion

Sharing the airway with the surgeon is exciting; it ensures the vigilance of the anaesthetist and close cooperation with the maxillofacial or ENT surgeon to recognise obstruction or dislodgement of the tracheal tube or LMA. If control and patency of the airway is lost, move the surgeon immediately and sort out the problem.

Anaesthesia for Orthopaedic Surgery

In the bad old days a trainee anaesthetist spent long hours in the evening and night watching young orthopaedic surgeons struggle with 'emergency' cases. Fortunately, it has been agreed that patients with, for example, hip fractures need their surgery performed as soon as practically possible, but in the safest environment. The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) recommends that such surgery should not be carried out by inexperienced surgeons and anaesthetists in the night. This work should be done on designated trauma lists during the day by appropriately trained staff.

General Considerations

The general considerations of anaesthesia for orthopaedic surgery are shown in Box 30.1. Often the extremes of age undergo orthopaedic surgery. Young people present commonly with trauma, while elderly patients often present for joint arthroplasty or with a fractured femoral neck. Age is not a contraindication to surgery, and you should learn to assess patients in terms of their biological age and physiological reserve, and not chronological age. Providing there are no major medical problems, elderly patients with hip fractures should have surgery on the earliest available trauma list. Otherwise, bed rest is associated with weakness, confusion, chest infection and deep vein thrombosis, with recovery from the delayed surgery prolonged. Postoperative mortality and morbidity remain high in these patients.

After major trauma, emergency surgery on patients with compound fractures is common. Associated spinal and neck injuries must be identified and appropriate treatment instituted before induction of anaesthesia. Traumatic injuries, such as fractured ribs and

Box 30.1 General considerations in orthopaedic anaesthesia

- Age
- Trauma or elective
- Concomitant injury or disease
- Use of tourniquet
- Infection
- Haemorrhage
- Methylmethacrylate cement
- Deep vein thrombosis prophylaxis
- Fat embolism

a fractured pelvis, are often associated with damage to abdominal viscera such as the spleen and liver.

Orthopaedic surgery in the elderly is usually complicated by concomitant diseases. Patients for joint arthroplasties may have medical problems such as rheumatoid arthritis. Patients with hip fractures may simply have tripped and fallen, but the fall may have followed a cerebral ischaemic attack or a cardiac arrhythmia. Even carpal tunnel syndrome is sometimes associated with hypothyroidism, acromegaly and – in younger patients – pregnancy.

Tourniquets are used commonly to exsanguinate the limb and keep blood out of the operative field. They must be placed carefully to avoid creasing of the skin, which results in irritation and blister formation. Tourniquets are not used in people with sickle cell disease, for fear of provoking a sickle crisis. The recommended maximum duration of tourniquet time is 90 minutes. Pressures used are 33–40 kPa (250–300 mmHg) for the arm and 46–53 kPa (350–400 mmHg) for the leg. They must be fixed securely to prevent loosening. Haemorrhage after release of the tourniquet can be brisk. In addition there may be a significant rise in end tidal carbon dioxide (ETCO₂), as well as a rise in other metabolites from the ischaemic limb such as lactate, potassium and hydrogen ions. Red cell transfusion is usual after major traumatic fractures, but is now less common during and after joint arthroplasties.

The cement used in orthopaedic surgery is polymethyl methacrylate. This liquid monomer becomes a solid polymer after reconstitution, and heat is generated. The bone cavity should be vented as the cement is inserted to prevent embolism of bone marrow and debris. Occasionally severe hypotension occurs as the cement is inserted, although the precise mechanism is unknown. This is referred to as bone cement implantation syndrome (BCIS), and very rarely can be associated not only with severe hypotension, but pulmonary hypertension, cardiac arrhythmias and even death. Thus extra vigilance is required at this time; the hypotension usually responds to the rapid administration of intravenous fluid although occasionally vasopressors are required.

Deep vein thrombosis remains the cause of significant morbidity and mortality after orthopaedic surgery. Thromboprophylaxis is essential for major lower limb surgery.

Fat embolism occurs occasionally after trauma or surgery involving the pelvis or long bones (0.5–2 per cent of patients). The initial symptoms and signs are as those of pulmonary thromboembolism. Fatty acid release causes diminished mental status, hypoxaemia, petechial haemorrhages and disseminated intravascular coagulation.

Anaesthesia for Specific Operations

Arm Surgery

Arm surgery can be carried out under regional anaesthesia, general anaesthesia or a combination of both. The indications and contraindications of each technique need to be considered, together with the wishes of the patient and the surgeon. Anaesthetic considerations and techniques are shown in Box 30.2.

Regional anaesthesia avoids the drowsiness, nausea and vomiting of general anaesthesia, but can be difficult to perform, is slow in onset and occasionally results in major complications such as pneumothorax and inadvertent intravascular injection (brachial plexus block). In addition phrenic nerve block is common which can cause respiratory problems in

Box 30.2 Anaesthetic considerations and techniques for arm surgery

- Intravenous access
- Use of tourniquet
- Duration of surgery
- Concomitant diseases
- Patient preference
- Surgeon preference
- Emergency or elective
- Regional anaesthesia ± sedation
 - brachial plexus block
 - individual nerve blocks at elbow
 - local anaesthetic injection at operative site
- General anaesthesia
 - +/- tracheal intubation
 - spontaneous ventilation or controlled ventilation

susceptible patients. Nevertheless, if the patient and surgeon agree, we prefer regional rather than general anaesthesia.

Leg Surgery

The anaesthetic considerations and techniques available for hip and knee surgery are shown in Box 30.3.

Elderly patients have fragile skin which must be cared for appropriately. Nerve palsies can arise; suitable padding should be used.

The advantages and disadvantages of regional anaesthesia are shown in Box 30.4. The advantages and disadvantages of general anaesthesia for hip surgery are shown in Box 30.5. We prefer regional anaesthesia, often with sedation, because of the decreased blood loss.

Fractured Neck of Femur

The continuing high mortality rate of this operation has ensured that it is no longer undertaken by junior trainees in anaesthesia and surgery. Many centres have protocols for managing these patients. Key points include:

1. Thorough preoperative evaluation – know the difficulties. These patients are often frail with poor physiological reserve. There are various scoring systems for kidney injury, delirium and cognitive function
2. Early surgery is invariably required – fixing the fracture is the best analgesic, preferably within 36 hours
3. Good preoperative analgesia – for example, fascia iliaca compartment blocks
4. Involvement of orthogeriatricians at an early stage has transformed the care of these patients. Orthopaedic surgeons have limited enthusiasm for perioperative medical problems in the elderly

Box 30.3 Anaesthetic considerations and techniques for hip and knee surgery

- Age
- Elective or emergency surgery
- Concomitant diseases
- Patient position
- Skin care
- Nerve damage from positioning of patient
- Haemorrhage
- Infection
- Methylmethacrylate cement
- General anaesthesia
 - spontaneous ventilation or controlled ventilation
- Regional anaesthesia $\pm$ sedation
 - spinal
 - epidural
 - femoral/sciatic nerve block
- Combination of general and regional anaesthesia
- Postoperative analgesia

Box 30.4 Advantages and disadvantages of regional anaesthesia for hip and knee surgery

- Advantages
 - no risks from general anaesthesia
 - decreased blood loss
 - decreased risk of deep vein thrombosis
 - better immediate postoperative analgesia
 - earlier mobilisation
 - decreased risk of respiratory infection
 - less vomiting and mental confusion
- Disadvantages
 - surgeon preference
 - patient preference
 - complications of technique used
 - hypotension
 - headache
 - difficult to perform in elderly

5. Spinal anaesthesia is generally preferred – avoid or minimise sedation, remember anticoagulants and valvular cardiac disease
6. Beware NSAIDs – renal impairment, and morphine – confusion. The following case study exemplifies a typical patient.

Box 30.5 Advantages and disadvantages of general anaesthesia for hip and knee surgery

- Advantages
 - often faster induction
 - patient preference
 - surgeon preference
 - better control of cardiovascular system
 - control of airway
 - avoids complications of regional anaesthesia
- Disadvantages
 - risks of general anaesthesia
 - slower recovery
 - slower mobilisation
 - more vomiting and confusion
 - increased risk of respiratory infection

Case Study

A 79-year-old woman is scheduled for a cemented hemiarthroplasty following a fall.

Preoperative Care

Take careful history and examination, pay particular attention to:

- The reason for the fall, and whether or not it was witnessed. Not all falls are the result of a simple trip. Some may be secondary to cardiac disease, such as an arrhythmia (including aortic stenosis), or a neurological cause such as transient ischemic attack. Enquire about speech changes and facial/leg/arm weakness.
- Other injuries from the fall (head, chest, limbs)?
- Ascertain past medical history and medications from the patient, or from their GP, or care home, as appropriate.
- Cognitive ability, do they have the capacity to give consent for the procedure?
- Ensure they are fully resuscitated. Patients often lose more than 500 ml blood from a fracture.
- Investigations should include ECG and haemoglobin, urea and electrolytes. If a cardiac or neurological cause is suspected, obtain urgent investigations, such as echocardiogram or CT scan of head.
- Whilst coexisting medical problems may need to be treated, a better patient outcome is usually associated with early surgery.
- Analgesia. Pain control is essential – regular paracetamol, and a fascia iliaca block (Chapter 33). NSAIDs are best avoided, and if opioids are administered, small doses should be titrated to effect. Beware of confusion and constipation.

Perioperative Care

The major choice is between regional and general. Currently there is little evidence to choose between the two, but the former is more popular. The combination of both is best avoided.

Regional anaesthesia: spinal analgesia is effective but careful management of hypotension is important. It may be technically difficult, and will require gentle positioning (perhaps with a small dose of fentanyl, remember midazolam is not an analgesic!). This technique is preferred by the authors. Ensure no contraindications, especially anticoagulants (such as clopidogrel, warfarin and new oral anticoagulants).

A simple general anaesthetic, with or without tracheal intubation and local nerve block is satisfactory.

Ensure arterial pressure and temperature are maintained. Consider invasive monitoring, particularly an arterial line. Keep a careful record of blood loss. Appropriate antibiotics are essential.

Postoperative Care

Patients will require oxygen, good pain control and thromboprophylaxis. Early mobilisation and physiotherapy are mandatory. Blood transfusion may be indicated. Sometimes level 2 care is indicated. Postoperative confusion is common and may be drug related (opioids, ketamine, benzodiazepines), or due to infection (chest or urine), electrolyte (such as hyponatraemia) or new cerebral events (e.g., stroke). Ensure patients receive appropriate medical input or medication for other conditions (e.g., Parkinson's disease).

Spinal Surgery

Special considerations apply to anaesthesia for spinal surgery (Box 30.6). Patients are usually prone, and corneal abrasions and pressure on the eyes must be prevented. The tracheal tubes used are reinforced to allow bending without kinking. They often need an introducer for insertion and, as they cannot be cut to a suitable size, may inadvertently pass into the right main bronchus. The tracheal tube must be well secured, as dislodgement when the patient is prone can be disastrous. The patient must be positioned correctly, often with the use of a Montreal mattress to support the chest and prevent compression of the abdomen. Abdominal compression decreases blood flow in the vena cava, but increases

Box 30.6 Anaesthetic considerations for spinal surgery

- Prone position
- Care of eyes
- Type of tracheal tube
- Difficult airway access – secure tube
- Difficult intravenous access
- Correct position of abdomen
- Specific nerve damage
- Infection
- Postoperative analgesia

flow through the epidural veins, making surgery more difficult and increasing blood loss. Nerves liable to damage include the brachial plexus, ulnar nerves, nerves at the wrist and the femoral nerves. These must be padded appropriately. Rarely postoperative visual loss may occur often due to ischaemic neuropathy resulting from globe pressure, low arterial pressure or raised central venous pressure (CVP). This is likely to occur with poor patient positioning, prolonged surgery and extensive blood loss.

These operations are often painful, and appropriate postoperative analgesia must be given and discussed preoperatively with the patient. Regional anaesthesia is particularly effective but disliked by many surgeons as it interferes with neurological assessment.

Conclusion

Trauma and arthritic disease will ensure that orthopaedic surgery is not going to disappear. Much orthopaedic anaesthesia can be conducted with regional techniques; it is an excellent environment in which to learn these skills. Remember that orthopaedic surgeons are often 'Black & Decker' people and sometimes have only a passing acquaintance with medicine.

Anaesthesia for Day Case Surgery

Day surgery is increasingly used for many procedures with about two-thirds of surgeries able to be performed as day cases. It is highly cost-effective, improves efficiency, whilst reducing the demand for, and not competing with, inpatient beds. For patients day surgery is preferable, and there may be quicker recovery and also a reduced risk of hospital acquired infections.

The assessment of day case patients is usually straightforward and is often delegated to senior nurses and new trainees. Surgeons frequently consider only the duration of surgery when deciding whether an operation can be undertaken on a day case basis. Their ability to ignore serious, chronic medical problems must never be underestimated. Most units have strict guidelines about the selection of patients for surgery as day cases. The most important considerations are the medical status of the patient, the potential surgical complications and the implications and side effects of anaesthesia. Typical selection guidelines are shown in Box 31.1.

In essence, the purpose of the guidelines is to ensure that relatively simple surgery with minimal complications is undertaken on healthy patients. General anaesthesia is

Box 31.1 Selection guidelines for day case surgery

- Medical: Should principally be on functional assessment not age, body mass index (BMI) or American Society of Anaesthesiologists (ASA) status etc.
 - ensure good control of diabetes
 - Uncontrolled cardiac disease/events within six months: unsuitable
 - Obstructive sleep apnoea (OSA) or scored as a high risk patient: unsuitable
- Surgical: duration relatively unimportant
 - minor and intermediate procedures, able to eat and drink soon after surgery
 - exclude procedures with significant postoperative pain
 - exclude procedures with significant risk of bleeding
 - exclude procedures with resultant significant disability
- Anaesthetic: no previous anaesthetic difficulties e.g., failed intubation
- Social: must live within 10 miles/1 hour of hospital, with toilet and telephone facilities
 - must not go home by public transport
 - must have a responsible, fit escort
 - must be supervised by a responsible, fit adult for 24 hours

Box 31.2 Discharge criteria for day case surgery

- Stable vital signs for 1 hour after surgery
- No evidence of respiratory depression
- Orientated to person, place and time (or return to preoperative status)
- Ability to maintain oral fluids
- Ability to pass urine (particularly after regional anaesthesia)
- Able to dress (consistent with preoperative status)
- Able to walk (consistent with preoperative status)
- Minimal pain
- Analgesics to take home
- Minimal nausea and vomiting
- Minimal surgical bleeding
- Suitable responsible adult escort present
- Written information for postoperative care including emergency arrangements, routine follow up, care of limbs following brachial plexus block etc, return to driving and alcohol intake

undertaken with short acting agents such as propofol or sevoflurane. Regional analgesia can be useful, such as brachial plexus block as well as short-acting spinal anaesthesia (e.g., prilocaine without the addition of opioids to reduce duration of motor block and bladder dysfunction). Strategies to reduce postoperative nausea and vomiting are important such as propofol infusions and/or antiemetics. Multimodal analgesia with judicious use of opioids and local anaesthetic infiltration where possible is invaluable.

It is essential to audit complications such as admission rates for overnight stay (and their reasons e.g., PONV, pain, surgical complications). Day case units may be within the main hospital and theatres, or in an isolated area away from the rest of theatres, or in a free standing remote unit. Provisions must be available to admit the occasional day case patient who has anaesthetic or surgical complications. After routine surgery the key decision is when to discharge the patient, and suitability is often assessed by the criteria shown in Box 31.2.

Conclusion

Careful assessment of the patient presenting for day case surgery is essential to spot the medical problems missed by the surgeons which will cause on the day cancellations. In addition, the social criteria for day surgery are also important and often overlooked. Adherence to the local selection guidelines should ensure a trouble-free anaesthetic, operation and recovery. However, do not expect all patients to obey instructions.

One author anaesthetised a local GP for a minor surgical procedure who discharged himself at noon to ride a motorcycle home for a light lunch before taking afternoon surgery!

Epidural and Spinal (Neuraxial) Anaesthesia

Neuraxial block forms an integral part of anaesthetic practice. It provides excellent analgesia for surgery, usually for the lower half of the body. Neuraxial block is very frequently used in obstetrics (see Chapter 34) as well as for lower limb and abdominopelvic surgery, with thoracic epidurals used also for thoracic surgery providing excellent intraoperative and postoperative analgesia.

In general, epidurals are sited with an epidural catheter and can be used for several days for analgesia (usually via an epidural infusion), whereas spinal injections are ‘single shot’ techniques with a relatively short duration of action (several hours). As epidural drugs need to diffuse into the cerebrospinal fluid (CSF) via the dura to take effect, the dose of drugs required for epidurals is about eight to ten times higher than that for spinal anaesthesia, e.g., 20–25 mls of epidural 0.5% bupivacaine will have a similar effect to about 2.5 mls of spinal 0.5% bupivacaine; in addition, the onset of an epidural takes some 20 minutes whereas a spinal takes only a few minutes for its onset. See Table 32.1.

There are several classes of drugs used for neuraxial anaesthesia, but the most commonly used are local anaesthetics and opioids. The former will block not only sensory nerves but will also block motor nerves and autonomic nerves. Therefore leg weakness, lack of proprioception, hypotension and urinary retention are predictable side effects. Opioids have the potential to cause respiratory depression and also urinary retention.

Whilst the use of spinal anaesthesia is still widespread, the use of epidurals particularly for postoperative pain relief has declined in recent years. Reasons for this include an increase in MIS (see Chapter 25) where epidurals are often not required, as well as some common problems with epidurals such as epidural failure, hypotension (requiring IV fluids

Table 32.1 Comparison of epidural and spinal anaesthesia

Epidural (or extradural)	Spinal (or intrathecal)
More difficult to learn	Rapidly learnt
Larger needle (Tuohy) used	Small needle used
Catheter inserted (extendable in duration)	Single shot (catheter rarely used)
Slower onset	Rapid onset
Patchy block more likely	Patchy block rare
Requires larger dose (x 8–10 that of spinal)	Only small doses required

Table 32.2 Requirements before starting neuroaxial anaesthesia

- Informed consent
- Vascular access
- Resuscitation drugs and equipment
- Sterility of anaesthetist
- Sterility of operative site
- No contraindications to procedure
- Correct dosage of local anaesthetic and opioid drugs

or vasopressors), urinary catheterisation and delayed mobilisation. Instead the use of other more peripheral blocks and analgesics have now become more common.

Before undertaking neuraxial anaesthesia, the criteria outlined in Table 32.2 must be considered and satisfied. Sterility of the anaesthetist does not refer to his or her reproductive capacity, but means wearing a gown, mask, hat and gloves.

Neuraxial and Regional Block Connectors (NR Fit)

The syringes and needles for neuraxial block are not compatible with the standard (Luer) fit but are different size. They are also coloured yellow and designed to prevent accidental wrong injection of drugs from other syringes. Clearly you must still draw up the correct drug into the NR syringe!

Epidural Anaesthesia

The epidural space runs from the base of the skull to the bottom of the sacrum at the sacrococcygeal membrane. The spinal cord, cerebrospinal fluid and meninges are enclosed within it (Figure 32.1).

The spinal cord becomes the cauda equina at the level of L2 in an adult and the cerebrospinal fluid stops at the level of S2. The epidural space is 3–6 mm wide and is defined posteriorly by the ligamentum flavum, the anterior surfaces of the vertebral laminae, and the articular processes. Anteriorly it is related to the posterior longitudinal ligament and laterally is bounded by the intervertebral foramina and the pedicles.

The contents of the epidural space are:

- nerve roots
- venous plexus
- fat
- lymphatics

The veins contain no valves and communicate directly with the intracranial, thoracic and abdominal venous systems.

Contraindications to epidural anaesthesia are shown in Table 32.2. Abnormal clotting may result in haemorrhage in a confined space if an epidural vein is punctured during the insertion of an epidural cannula. An epidural haematoma then causes spinal cord compression. Local skin infection may introduce bacteria into the spinal meninges with the risk of an abscess or meningitis. Similarly with septicaemia – if a vein is punctured then the small haematoma is a good culture medium for bacteria.

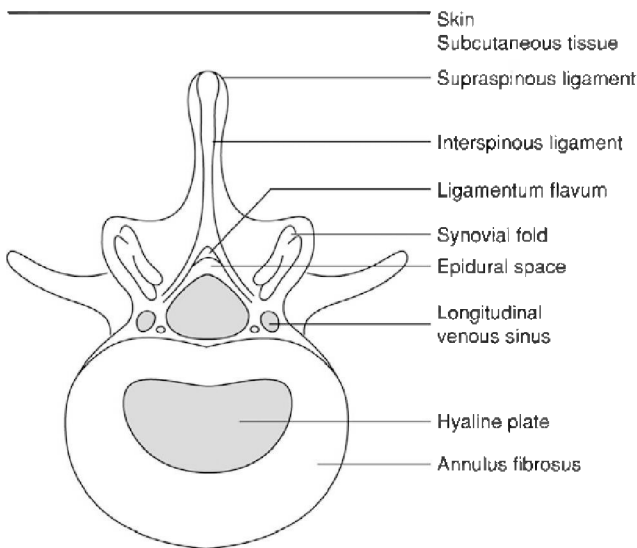


Figure 32.1 Anatomy of the epidural space

Although the evidence that spinal disorders are exacerbated by the insertion of an epidural catheter is poor, patients are often quick to blame the anaesthetic procedure. The same principle applies to patients with neurological problems such as multiple sclerosis. The evidence that drugs that mildly affect clotting or platelet function (e.g., aspirin) cause abnormal bleeding in the epidural space and increase the risk of an epidural haematoma is minimal.

The Tuohy needle is either 16 or 18 gauge. It is 10 cm long: 8 cm of needle and 2 cm of hub. It is marked in centimetres and has a curved 'Huber' tip (see Figure 32.2). The epidural catheter has three holes at 120° alignment, with the holes 2 cm from the end of the catheter. The catheter is marked in centimetre gradations up to 20 cm. The filter has a 0.2 µm mesh that stops the injection of particulate matter, such as glass and bacteria, into the epidural space.

The correct technique of insertion of an epidural catheter must be learnt under careful supervision. The conditions listed in Table 32.3 must be met. An intravenous infusion of either crystalloid or colloid is set up to give a 'fluid load' of about 500 ml before the local anaesthetic is injected. This is undertaken to decrease the likelihood of hypotension with the onset of the epidural block. Atropine and a vasopressor should always be available before starting the block.

The procedure can be done in either the lateral or sitting position, and ideally the spine should be flexed. A slow, controlled advance of the Tuohy needle is essential, using a syringe and a loss-of-resistance technique. The needle passes through skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum and finally enters the epidural space. The ligaments resist the injection of air or saline, but when the needle enters the epidural space the resistance is lost.

The choice is between using air or saline to identify the epidural space. The advantages of air are that:

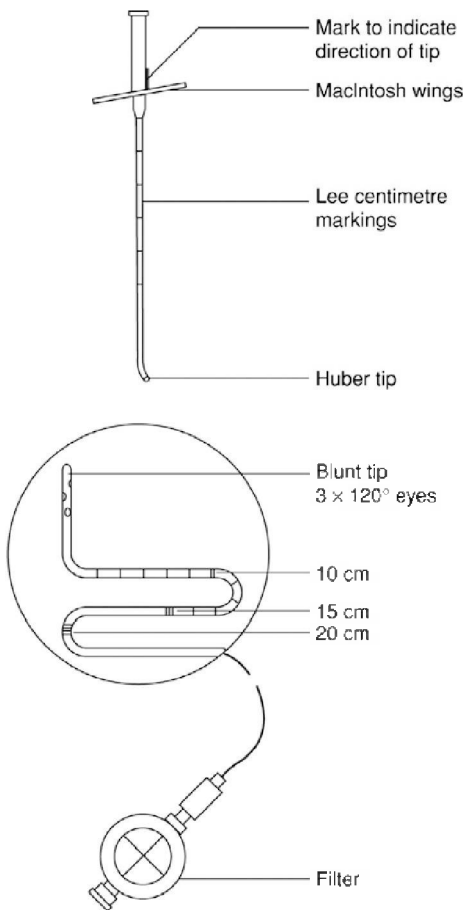


Figure 32.2 Tuohy needle, epidural catheter and filter

- any fluid in the needle or catheter must be cerebrospinal fluid
- there is less equipment on the tray
- it is cheaper

The disadvantages of air are that:

- injection of large volumes may result in patchy blockade
- there is a theoretical risk of air embolus

The advantages of saline are that:

- it is a more reliable method of identifying the epidural space
- the catheter passes more easily into epidural space

The disadvantages of saline are that:

- fluid in the needle or catheter may be either saline or cerebrospinal fluid; the latter is warmer and contains glucose, but rapid clinical decisions are difficult
- there are additional fluids on the tray, with increased risk of error

Table 32.3 Absolute and relative contraindications to epidural anaesthesia

- Absolute
 - patient refusal
 - significant coagulopathy
 - a) due to current drugs such as direct acting oral anticoagulants (DOACs), clopidogrel and heparin
 - b) Other disorders of haemostasis such as thrombocytopaenia, liver failure, haemophilia, Von Willebrands (vWB) disease, etc.
 - infection – adjacent to insertion site or systemic such as septicaemia
 - allergy to local anaesthetic drug
- Relative
 - raised intracranial pressure
 - hypovolaemia
 - chronic spinal disorders
 - central nervous system disease
 - fixed cardiac output states, e.g., aortic stenosis

We recommend you become thoroughly familiar with either air or saline before trying the alternative method. There is no ‘correct’ method but saline is more popular.

The epidural space is usually found at a distance of about 4–6 cm from the skin. Place the catheter rostrally and, using the centimetre markings on the needle and catheter, insert 3 cm of catheter into the epidural space.

The filter and catheter, once correctly positioned and fixed, must be aspirated to ensure that no blood or CSF can be withdrawn. Many people also use a ‘meniscal drop’ too – observing saline meniscus in the epidural catheter to fall once the epidural catheter is in situ. The local anaesthetic drug is given in small, incremental doses to reduce the risk of complications.

The complications of epidural blockade, assuming no technical difficulties in the location of the space and the siting of the catheter, are shown in Tables 32.4 and 32.5.

Hypotension results from a decreased venous return to the heart as a consequence of vasodilation induced by the sympathetic blockade. The ‘fluid load’ helps to prevent hypotension, but a sympathomimetic or vasoconstrictor is more logical, such as ephedrine in 3–6 mg intravenous increments, or phenylephrine as either a bolus or infusion (the latter particularly in obstetrics).

If not correctly sited, two unwanted and potentially disastrous misplacement of an epidural catheter are either intravenous or intrathecal (i.e., in the CSF).

- (a) The risks of the intravenous injection of local anaesthetic are minimised by aspiration of the catheter and by giving small incremental doses. If blood is aspirated, usually the catheter is removed and the epidural re-sited in a different space. Occasionally, the catheter can be withdrawn from the epidural vein and no blood aspirated. Then the catheter must be flushed with saline to ensure it is not in a vein before further use.

Table 32.4 Complications of epidural anaesthesia

- Severe hypotension
- Accidental intravenous injection
- Dural puncture
 - Massive spinal anaesthetic
 - Headache (especially young patients)

Table 32.5 Other complications of epidural anaesthesia

- Leg weakness
- Shivering
- Atonic bladder
- Contraction of the small bowel
- Backache
- Isolated, reversible nerve damage from catheter/needle trauma
- Permanent nerve injury from epidural haematoma or abscess (both of which can cause spinal cord compression)
- Meningitis

(b) Accidental dural puncture occurs when the needle or catheter is inserted into the cerebrospinal fluid. If this is not recognised and a full epidural dose of local anaesthetic is injected into the wrong place, a massive spinal anaesthetic will result, with apnoea, severe hypotension and total paralysis ('total spinal'). The lungs have to be ventilated and the circulation supported during this period. For this reason, an epidural 'test dose' of 2–3 ml of local anaesthetic is given by many anaesthetists before the full dose is injected (e.g., 2% lignocaine). In the epidural space this dose of local anaesthetic has little effect, but in the cerebrospinal fluid an extensive block occurs rapidly. After 10 minutes the epidural dose of local anaesthetic is given if no adverse effects are noted.

In addition, a severe postural headache following dural puncture (post dural puncture headache – PDPH) is managed by resting the patient in a flat position (or even prone), simple analgesics, adequate hydration and mobilisation and, if necessary, a 'blood patch'. The dural puncture can be sealed by placing 20 ml of the patient's blood into the epidural space under aseptic conditions. The resulting clot will rapidly stop the leak and is effective in the majority of patients. Two anaesthetists are required for this manoeuvre.

Opioids can also be given in the epidural space to prolong the effects of local anaesthetics and to provide postoperative analgesia. They have different complications (Table 32.6), of which respiratory depression is the most serious. Regular monitoring of respiratory function is essential (see Chapter 37).

Very serious sequelae of epidurals are fortunately rare. Remember:

Table 32.6 Complications of neuraxial opioids

- Delayed respiratory depression
- Drowsiness
- Itchiness
- Nausea and vomiting
- Urinary retention

- (a) Injection of the wrong drug can be catastrophic (always double check ANY drug prior to administration).
- (b) An abscess or haematoma will cause a space occupying lesion within the vertebral canal leading to spinal cord compression. Patients will complain of a sudden onset of severe back pain and leg weakness. This is a neurosurgical emergency: the patient will need a confirmatory MRI and urgent (<6 hours) spinal surgical decompression.
- (c) Permanent neurological injury is thankfully rare, with an incidence of about 1:50,000 for epidurals (with a slightly lower rate for spinal anaesthesia)

Spinal (Intrathecal or Subarachnoid) Anaesthesia

This is the deliberate injection of local anaesthetic into the cerebrospinal fluid (CSF) by means of a lumbar puncture. It is normally given as a single injection, but can be used in conjunction with epidural anaesthesia (combined spinal–epidural anaesthesia) for longer procedures.

The incidence of headache following dural puncture is dependent on the size and type of spinal needle. Not surprisingly, the smaller the diameter of the needle, the lower the incidence of headache (remember, 27 gauge is smaller than 25 gauge).

Atraumatic spinal needles, such as Whitacre and Sprotte, split, rather than cut, the dura and also reduce the risk of headache, as opposed to Quincke needles, with a sharp cutting bevel, which will be familiar to you as the usual needles for injection, as illustrated in Figure 32.3.

Local anaesthetic solutions for spinal anaesthesia are isobaric or hyperbaric with respect to the CSF. Isobaric solutions are claimed to have a more predictable spread in the CSF, independent of the position of the patient. Hyperbaric solutions are produced by the addition of glucose, and their spread is partially influenced by gravity. Many factors determine the distribution of local anaesthetic solutions in the CSF (Box 32.1); this makes prediction of the level of blockade difficult.

The complications of spinal anaesthesia are the same as for epidural anaesthesia. Neuronal blockade is more rapid in onset, so the side effects, such as hypotension, occur promptly. In spinal anaesthesia the duration of the block is variable, but it is usually shorter than that of epidural anaesthesia.

Combined Spinal Epidural Anaesthesia

In theory combining both of these techniques is an attractive concept, with the rapid onset of a spinal block which can be extended with an epidural catheter. The usual method is

Common tip designs for spinal needles

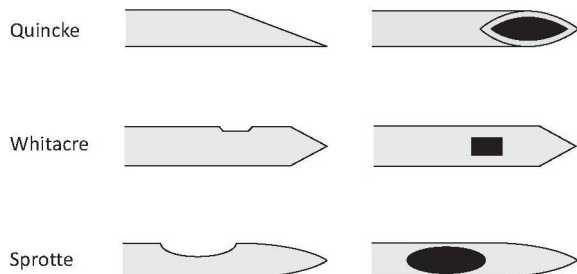


Figure 32.3 Comparison of spinal needles From Spinal anaesthesia. Christina L. Beecroft. *Anaesthesia & Intensive Care Medicine*. Volume 10, Issue 11, Pages 549–551 (November 2009). DOI: <https://doi.org/10.1016/j.mpaic.2009.08.010>

Box 32.1 Factors influencing distribution of local anaesthetic solutions in CSF

- Patient age
- Local anaesthetic drug
- Baricity
- Dose of drug
- Volume of drug
- Turbulence of cerebrospinal fluid Increased abdominal pressure
- Spinal curvatures
- Position of patient
- Use of vasoconstrictors
- Speed of injection

a ‘needle through needle’ technique: an epidural is sited in the usual manner following which an extra long spinal needle is used for the intrathecal injection. The spinal needle is removed and the epidural catheter is then inserted, then finally the Tuohy needle withdrawn.

Caudal Anaesthesia

Whilst less frequently used, the caudal space is a continuation of the epidural space in the sacral region. The signet-shaped sacral hiatus is formed by the failure of fusion of the laminae of the fifth sacral vertebra. The hiatus is bounded laterally by the sacral cornua and is covered by the posterior sacrococcygeal ligament, subcutaneous tissue and skin. The epidural space is located by passing a needle through the sacral hiatus. The caudal canal contains veins, fat and the sacral nerves. The cerebrospinal fluid finishes at the level of S2.

Table 32.7 Dermatomal levels at various anatomical landmarks

Anatomical landmark	Dermatomal level
Nipples	T4
Xiphisternum	T6
Umbilicus	T10
Symphysis pubis	L1/T12

Caudal anaesthesia is used for operations in areas supplied by the sacral nerves, such as anal surgery and circumcision. The precautions are the same as those described for epidural anaesthesia. The needle must be aspirated after insertion to exclude blood and cerebrospinal fluid. The complications are the same as for epidural anaesthesia, although motor blockade can be a major problem in the early postoperative period if the patient wants to walk.

Hypotension is uncommon, as the neuronal blockade usually does not spread rostrally to reach the sympathetic chain.

The extent of a block can be measured by the absence of pain or temperature sensation at a dermatomal level (Table 32.7). The former is tested with a pin and the latter with ethyl chloride spray.

Conclusion

Regional anaesthesia is enjoyable for the anaesthetist and provides excellent analgesia for the patient. There are, of course, significant potential risks, but these can be minimised by careful patient selection and learning good technical skills to match understanding of essential anatomy, physiology and pharmacology.

Start early in your career – make the epidural and subarachnoid spaces familiar territory.

Common Regional Blocks

Nearly all operations can be done under regional anaesthesia. However, for several reasons, often convenience, most operations are performed under general anaesthesia or under a combination of both regional and general anaesthesia. However regional anaesthesia alone has advantages for rapid recovery, avoiding many of the problems associated with general anaesthesia.

There are several blocks that you should learn early in your career as they are invaluable for intraoperative and postoperative analgesia. Anaesthetists like sticking needles into veins and around nerves! Some complex nerve blocks contribute little to the patient's welfare. Perform a block only, if there is a sound indication otherwise there may be a complication that doesn't justify its use!

If a regional block is performed it is important to explain to the patient what to expect. For example, an upper limb block may result in a weak and numb arm for several hours, which can be worrying for patients.

There are important considerations before undertaking any regional block – see Box 33.1.

Equipment for Nerve Blocks

Nerve blocks used to be performed blindly, that is without the use of a nerve stimulator or ultrasound. Large volumes of local anaesthetic were injected in a fan-like fashion in the general direction of the nerve(s) in the hope that some would hit the correct site. Curiously, this often worked well, but technology has greatly enhanced the success of regional anaesthesia.

Box 33.1 Essential considerations when performing nerve blocks

- Indication
- Contraindication
- Anatomical knowledge
- Consent
- Vascular access
- Awake, sedated, or combined with general anaesthesia
- Sterility
- Technique
- Local anaesthetic dose and toxicity
- Resuscitation drugs including intralipid

Nerve stimulators generate an alternating current which, when applied directly to a nerve with a small needle (often 24 G), causes the nerve to fire and a muscle or a muscle group to contract. This movement can be seen directly. The lower the voltage necessary to elicit movement, then the closer to the nerve the stimulating electrode must be. Voltages of < 1 mV indicate that the needle is near to, or even in, the nerve sheath. After aspiration of the needle the local anaesthetic can be given. Sometimes you cannot see a muscle twitch when you are sure you are in the correct space. This will puzzle you – perhaps you have used a neuromuscular blocking drug (NMBD) as part of the anaesthetic technique – a paralysed muscle will not twitch! Ultrasound machines have revolutionised regional anaesthesia and are widely regarded as the gold standard to perform blocks (as well as some vascular cannulations – see Chapters 5 and 9). Arteries pulsate, veins compress and nerves stay the same shape. You have to familiarise yourself with these machines and know the gain of the machine so that you are aware that the nerve is within the field of view. You must also orientate yourself at the start by recognising left and right. Anatomical knowledge is fundamental to the successful use of ultrasound.

However, some blocks can be performed with or without ultrasound – the three ‘double click’ blocks. These blocks that are easy to perform and provide good analgesia are:

- Fractured neck of femur and hip surgery – fascia iliaca block
- Inguinal hernia surgery – ilio-femoral and ilio-hypogastric block
- Abdominal surgery – transversus abdominis plane (TAP) block

All of these blocks utilise a blunt needle because it provides a greater sensitivity when you ‘click’ through the relevant sheaths and muscles. We often further blunt ‘blunt needles’ by tapping them against the inside of an opened ampoule. The first two of these blocks are often undertaken ‘blind’.

Fascia iliaca block is often undertaken in the Accident and Emergency Department by anaesthetists or trained doctors to relieve the pain of patients who have a broken hip. This block provides good analgesia for 12–24 hours, and minimises the use of opiates in this vulnerable group. It has the great advantage that it is easy to perform. The landmarks are the symphysis pubis and the anterior superior iliac spine. A line is drawn between these two points and this line is divided into thirds. The point between the middle and outer third is marked and a spot 2.5 cm below this is identified. The needle is inserted here and passes through two planes or two ‘clicks’ and then stopped. After aspiration the local anaesthetic is injected. The local anaesthetic passes through the plane under the iliacus muscle and blocks those branches of the femoral and obturator nerves that supply the hip. It is a useful intraoperative anaesthetic block for hip surgery too.

The intra- and postoperative analgesic requirements for patients undergoing open inguinal hernia repair are minimised by the use of a combined simple ilio-inguinal and ilio-hypogastric nerve block that is performed blindly one finger’s breadth medial to the anterior superior iliac spine. Again, a blunt needle ‘double click’ identifies the correct plane that contains the nerves to the inguinal canal. The inguinal canal is also supplied by the genitofemoral nerve which lies in close proximity to the femoral artery and nerve. An injection to block this nerve is difficult and we don’t do it because an accidental injection around the femoral nerve will cause quadriceps weakness. Your day case inguinal herniorrhaphy patient will limp home bemused as to why he cannot walk properly. Keep blocks simple.

A TAP block is best undertaken using ultrasound; the correct plane is easy to identify. The intercostal nerves lie under the transversalis fascia and a ‘double click’ identifies the correct plane. The block is most easily performed in the mid- axillary line at the mid-point of the 12th rib and the anterior iliac crest. Large volumes of local anaesthetic are used to ensure an adequate spread of local anaesthetic to block several intercostal nerves and reduce pain after a laparotomy.

Once you are familiar with ultrasound, you can master, with supervision, the major seven ‘Plan A’ blocks, as seen in Figures 33.1 to 33.7. These inplane ultrasound guided blocks provide analgesia in the areas shown below.

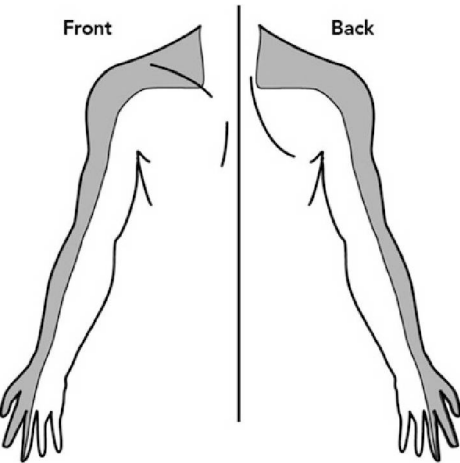


Figure 33.1 Interscalene brachial plexus block
Surgery above the shoulder

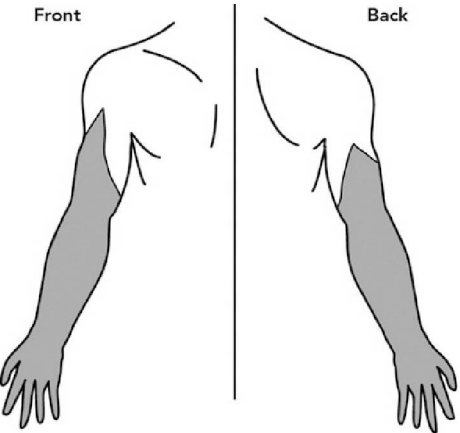


Figure 33.2 Surgery below the shoulder

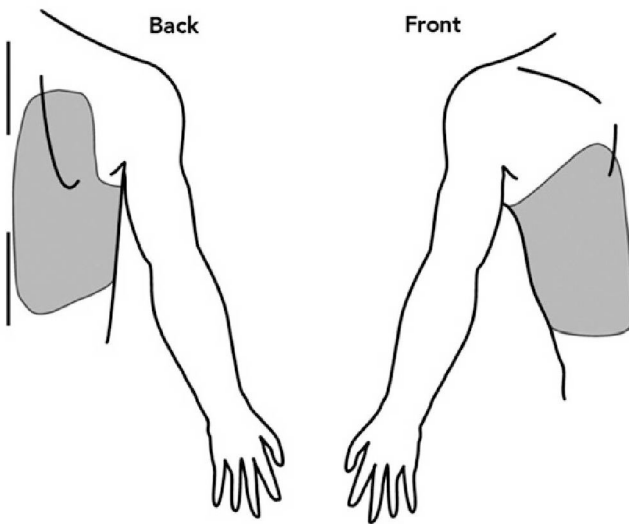


Figure 33.3 Erector spinae plane block.
For rib fractures and chest wall surgery

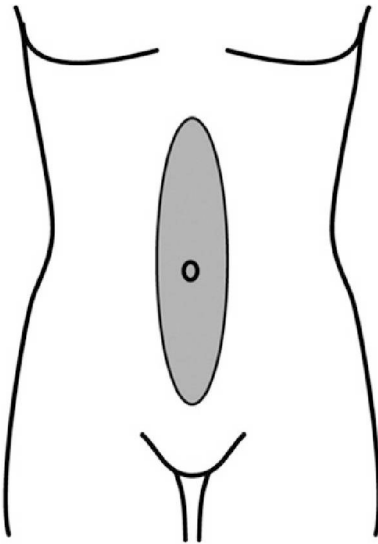


Figure 33.4 Rectus sheath block.
Midline abdominal surgery

Surgeons' Blocks

Surgeons often infiltrate the wound to minimise pain after surgery, and sometimes they place catheters themselves, for example, rectus sheath, paravertebral blocks or wound catheters. They will invariably ask you how much local anaesthetic they can use. It is no use telling them that the maximum dose of bupivacaine is 2 mg/kg. Work it out as shown in



Figure 33.5 Femoral nerve block.
Hip and knee surgery



Figure 33.6 Adductor canal block.
Knee surgery

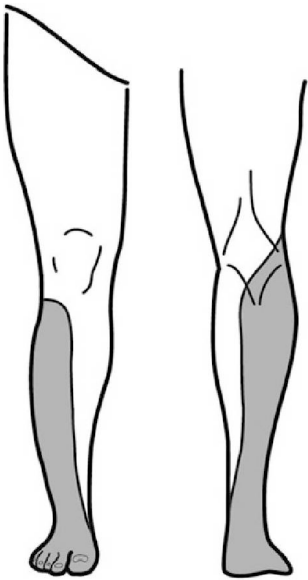


Figure 33.7 Popliteal/sciatic nerve block.
Foot and ankle surgery

Chapter 16 and tell them to use 'x ml of bupivacaine y%' and they will be happy. Err on the side of caution, surgeons can get carried away when they have a needle and syringe in their hands.

Conclusion

Regional anaesthesia is enjoyable. A perfect block means a happy patient and a happy anaesthetist. Learn carefully from an experienced senior colleague. Distrust enthusiasts who claim never to have had complications following regional anaesthesia. The major complications are inadvertent intravenous injection, direct nerve damage and wrong sided block. Always aspirate before injecting a local anaesthetic. Make sure that you always STOP BEFORE YOU BLOCK – thus ensuring you perform the block on the CORRECT side.

Obstetric Anaesthesia

Early attendance in the maternity unit is important for novice anaesthetists. Colleagues will talk of frightening moments of great stress working in isolation and unconsciously cause anxiety in trainees. It is a privilege to care for a woman in labour but it is important to understand that you are working in a different environment with unique physiological demands. You need to be able to trust your skills and care for the lives of both mother and baby.

The physiology of the pregnant patient is shown in Box 34.1. Anaesthetists have three main functions in the labour ward. These are the:

- provision of epidural analgesia to the labouring parturient and generally caring for the patients in labour
- provision of regional and general anaesthesia in the obstetric theatres
- care of patients in the recovery area and maternity HDU

The best piece of advice we were given when we started obstetrics was to know about all the patients in the labour ward. This way you can anticipate problems. Effective epidural analgesia can be started on women likely to come to theatre and you can avoid being suddenly presented with major problems in patients who have been in the labour ward for hours.

Labour Analgesia

Analgesic requirements in labour vary between individuals. The basic techniques available are shown in Box 34.2.

Box 34.1 Physiology of the pregnant patient

- Up to 40–50% (2 l) increase in blood volume
- 20% increase in red blood cell mass (dilutional anaemia)
- Aorto-caval compression by the uterus
- Hypercoagulable state
- Up to 60% increase in oxygen requirement (increased tidal volume)
- Diaphragm pushed cephalad (physiological breathlessness)
- Airway oedema (changing Mallampati score in labour)
- Increased weight and large breasts (difficult laryngoscopy)
- Decreased oesophageal sphincter tone (indigestion and reflux)
- Delayed gastric emptying

Box 34.2 Analgesia in labour

- Some patients require none
- Entonox (a mixture 50% nitrous oxide and 50% oxygen)
- Systemic opiates
- Complementary techniques: transcutaneous electrical nerve stimulation (TENS), water birth, hypnotherapy, acupuncture
- Regional anaesthetic techniques – epidural, spinal or a combination of the two

In essence, within the labour ward intra-partum analgesia is straightforward.

The parturient woman has a choice of analgesic options ranging from complementary techniques and/or Entonox to the use of analgesic agents and neuroaxial blockade, with the latter always requiring an anaesthetist. When an epidural is requested, some women may have already received Entonox, simple analgesics or opioids such as pethidine. An anaesthetic novice often has little experience in inserting epidurals, so a labouring patient is not ideal for learning, therefore the technique is commonly taught on manikins and in main theatres first. Every anaesthetist may have a slightly different technique but a good approach is always to organise your tray and equipment prior to starting, so that you can ensure you are not suddenly missing a vital piece of equipment when you are mid-procedure. When inserting the epidural, it is important to be in a comfortable and steady position to be able to slowly advance the Tuohy needle 1mm at a time with full control using a continuous pressure saline technique. Once inserted, the most important part is to adequately secure the epidural in place as it is the most upsetting 3 am call when an epidural has simply fallen out due to poor securing.

Trainees will only be expected to complete these procedures once they have passed their obstetric competencies.

Once the epidural is in place, a 'test dose' is administered (see Chapter 32). The epidural mixture usually contains a 'low dose' mix of local anaesthetic agent (bupivacaine 0.1%) with an opioid (fentanyl 2micrograms/ml). This 'low dose' allows patient mobility and is usually administered every one to two hours to ensure good analgesic effect. Some units use spinal analgesia initially before starting epidural analgesia but the majority use an epidural from the outset. About half the maternity units in the United Kingdom use midwives to top up the epidural and the rest use patient-controlled epidural analgesia (PCEA) devices. It is claimed that PCEA provides better analgesia as the patient controls their analgesic requirements and uses less local anaesthetic.

It is extremely important to monitor the labouring woman during the first dose to ensure an adequate response is seen with no adverse effects. A total/high spinal is a rare but feared event by many anaesthetists, especially if the epidural has been difficult to insert and would present with sudden ascending full blockade together with haemodynamic instability.

Epidural analgesia is further discussed in Chapter 32. Consent for this procedure always plays an important role and should be conducted thoroughly. Immediate complications are a major problem when performing epidural analgesia in labour. Post-dural puncture headache is a serious problem that is best avoided. A new mother needs to be up and active but the pain can be incapacitating and evidence suggests simple analgesics, hydration and caffeine in selected cases and safe dosing. This can be frustrating for the patient and requires

assiduous daily follow-up. Occasionally, the severity of the headache warrants an epidural blood patch.

Anaesthetists often run into trouble when caring for a patient in whom someone else has performed epidural analgesia. Always aspirate on any epidural catheter before injecting drugs as occasionally the epidural catheter is intrathecal (in the cerebrospinal fluid- CSF). If this occurs, an epidural top up results rapidly in total spinal anaesthesia with severe distress for patient and anaesthetist.

Remifentanyl patient controlled analgesia (PCA)

Some women may be unsuitable to receive neuraxial blockade due to contraindications to regional intervention such as spinal cord or vertebral pathology, anticoagulation, coagulopathy, severe sepsis or maternal refusal. In cases of intrauterine death or termination of pregnancy due to fetal abnormality the choice of a remifentanyl PCA may be preferred by the patient. Whilst it can provide good analgesia in labour, meticulous monitoring is essential as maternal deaths have been reported when inadequacies of monitoring or administration have occurred. Most departments, therefore have strict protocols for the setup up and essential monitoring when administering a remifentanyl PCA. When asked to set up a PCA always conduct a two-person check on the drug preparation and pump set up prior to attaching it to the patient.

Interventional Procedures

In the operating theatres elective and emergency work is undertaken. The elective procedures are normally Caesarean sections and occasionally cervical sutures. Nearly all these procedures are done under regional anaesthesia (spinal, epidural or combined spinal-epidural). This eliminates the risks of general anaesthesia (failed intubation, hypoxia, aspiration and the effects of general anaesthesia on both mother and fetus). Regional anaesthesia allows the mother to be awake for the operation, earlier mobilisation and provides better postoperative analgesia. The principles of operative procedures in the labour ward are shown in Box 34.3.

Box 34.3 Principles of operative obstetric anaesthesia

- Premedication: sodium citrate 30 ml < 15 min before the procedure, ranitidine 150 mg 12 hours and 2 hours preoperation, if possible
- Good intravenous access, 16 g or 14 g (ensure it is working!)
- Preload of 500 ml crystalloid
- Left lateral tilt (15°) to avoid aorto-caval compression
- Maintenance of arterial pressure (ensure phenylephrine and ephedrine are available)
- Phenylephrine infusion readily available
- Antibiotics IV
- Adequacy of block (T4 bilaterally) with ethyl chloride spray (temperature difference)
- Oxytocin upon delivery intravenously and slowly
- Alternative uterotonics prepared in the case of atony
- Careful transfer to the recovery area

Caesarean sections (Lucas classification) are categorised as follows:

- Category 1. Immediate threat to the life of the woman or fetus
- Category 2. Maternal or fetal compromise which is not immediately life threatening
- Category 3. No maternal or fetal compromise but needs early delivery
- Category 4. Delivery timed to suit woman and staff

Emergency obstetrics can be fraught. Patients come for Caesarean section (regional or general anaesthesia), for instrumental delivery or for the complications of delivery such as haemorrhage. This situation is always stressful and managed more easily if regional anaesthesia is already present. Topping up an epidural catheter you had the foresight to insert in labour is easier than embarking upon general anaesthesia. However, general anaesthesia has to be undertaken not uncommonly and a full assessment of the anticipated ease of intubation should be undertaken. Call for help if you are worried; we do without hesitation. A new trainee will never be left alone but those in their second year of training may be.

The anxiety of a failed intubation in general anaesthesia can be minimised by meticulous planning and by checking equipment carefully. The health of the mother is the priority.

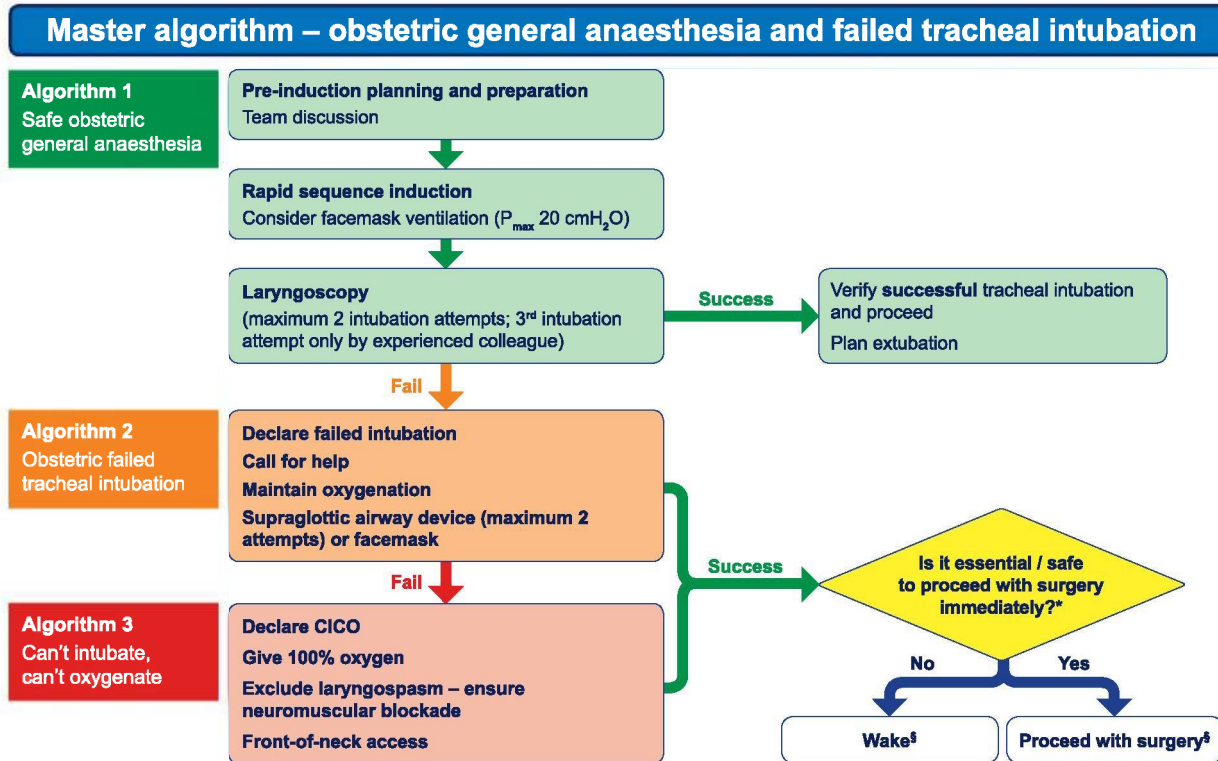
The Obstetric Anaesthetist's Association/Difficult Airway Society (OAA/DAS) algorithm for failed tracheal intubation in the obstetric patient should be followed (see Figure 34.1) and important management points are displayed in Box 34.4.

High Dependency Obstetrics

Most units have a two to four bedded unit HDU where the ill obstetric patient is cared for. These are normally staffed by HDU nurses and midwives. Obstetric patients are young and the effects of illness are not obvious, even when very sick. The physiological changes of pregnancy can easily mask the early signs of sepsis and haemorrhage. An obstetric patient may lose 1.5 l of blood before any cardiovascular changes indicative of haemorrhage are seen. All units now have adopted Maternal Early Warning Scoring (MEWS) charts to try to identify the

Box 34.4 Management of failed obstetric intubation

- Prepare a plan B pre-induction – awaken patient or continue anaesthetic?
- Rapid sequence induction – consider facemask ventilation ($P_{\text{max}} < 20$ mmHg)
- Two intubation attempts plus a third attempt by a more experienced colleague
- Call for help
- Maintain oxygenation
- Optimise position
- Use bougie or stylet
- Videolaryngoscope as first choice device
- Supraglottic airway device (2nd generation preferred)
- Two-person facemask technique
- If still unable to ventilate declare a 'can't ventilate can't oxygenate' emergency
- Exclude laryngospasm – ensure neuromuscular blockade
- Front of neck access



*See Table 1, §See Table 2

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Figure 34.1 Algorithm for failed tracheal intubation (jointly from the Obstetric Anaesthetists' Association and Difficult Airway Society)
Mushambi, M. C., Kinsella, S. M., Popat, M., Swales, H., Ramaswamy, K. K., Winton, A. L. and Quinn, A. C. (2015). Obstetric Anaesthetists' Association and Difficult Airway Society guidelines for the management of difficult and failed tracheal intubation in obstetrics. *Anaesthesia*, 70: 1286–1306. <https://doi.org/10.1111/anae.13260>.

deteriorating mother early. The first person called is usually the obstetric registrar who will often ask the resident anaesthetist for help.

Maternal death is a major catastrophe. Pre-existing cardiac disease is a major cause but the major causes of obstetric death are thromboembolism, cardiac disease, suicide, obstetric haemorrhage and sepsis.

Conclusion

Obstetrics can be very satisfying but is also very frightening when it goes wrong. Attend the labour ward early in your career and become familiar with the way it works. Gain confidence in your regional anaesthetic techniques and you will derive great satisfaction from helping women at a key time in their lives.

Anaesthesia in the Corridor

Occasionally you will be asked to undertake anaesthesia away from the operating theatres. Inexperienced anaesthetists are not supposed to be involved with such work, as 'playing away from home' is more hazardous.

Within the hospital, anaesthetics may be given in:

- psychiatric unit for electroconvulsive therapy
- accident and emergency department
- coronary care unit
- radiology department

Outside the hospital you may be asked to maintain anaesthesia during the transfer of patients between hospitals.

The principles and practice of safe anaesthesia remain the same regardless of the site. The essential requirements are shown in Box 35.1, and, if these are not met, the patient should be transferred to a safe environment. A senior anaesthetist must be called if any anaesthetic difficulty is anticipated.

Box 35.1 Minimum requirements for conduct of anaesthesia

- Qualified, experienced assistance
- Checked anaesthetic machine
 - medical gas supplies
 - vaporisers
 - breathing systems
 - ventilator
- Adequate suction
- Adequate table tilt
- At least two working laryngoscopes
- Appropriate range of face masks, airways, tracheal tubes
- Minimal monitoring equipment with alarms including capnography
- Appropriate drugs available
- Resuscitation drug box present
- Defibrillator working
- Appropriate recovery facilities and staff

In general, anaesthesia needing a rapid sequence induction should be carried out in the main operating theatres.

Crises and complications can occur anywhere, and you must be prepared. Do not be persuaded to work with inadequate facilities. Local medical staff can be very reassuring about the safety of anaesthesia over the last 20 years in some far corridor of the hospital.

Electroconvulsive Therapy

Therapeutic convulsive therapy is used for the treatment of severe psychotic states including depression, bipolar disorder and catatonia. Many patients are frail, but are usually well prepared by the psychiatrists. The anaesthetist must consider the points shown in Box 35.2 in addition to the minimum requirements for the provision of anaesthesia. Care is required and advice sought from a cardiologist if the patient has a cardiac pacemakers or implantable cardioverter defibrillator (ICD).

After induction of anaesthesia, the convulsion is modified by the use of small doses of suxamethonium (25–50 mg), which makes the patient apnoeic for a few minutes. Muscle pain after anaesthesia is not a major problem. The teeth must be protected by a bite block when the ECT is commenced.

Since the anaesthetist must not touch the patient at the initiation of the convulsion, adequate oxygenation must be ensured before treatment.

Accident and Emergency Anaesthesia

The anaesthetist is a frequent visitor to the Accident and Emergency Department to assist in cardiopulmonary resuscitation. Anaesthesia in this environment used to be common and was undertaken in difficult conditions; monitoring and recovery facilities were often non-existent. One author has been involved with ‘casualty lists’ – these were hazardous for the patients and apparently character-building. They should no longer occur for us, and surgery and anaesthesia should be undertaken in the main operating theatres.

Radiological Procedures

Again, the basic requirements of safe anaesthesia must be met. For scanning procedures, the anaesthetist often has to leave the patient and move to the scanning room, returning to monitor the patient physically between scans. You must be able to see the patient, either through a window or by remote television, at all times. The monitoring equipment must always be clearly visible. In radiological procedures, the anaesthetic circuit is often 2–3 m long, and access to the airway and venous cannula is difficult during scanning. General anaesthesia with control of the airway is nearly always safer than sedation. In particular, never sedate a patient with a head injury. Beware of the ‘urgent’ patient with abdominal bleeding who is sent for a CT scan before

Box 35.2 Considerations for electroconvulsive therapy anaesthesia

- Remote-site anaesthesia
- Mental state of patient
- Modified convulsion
- Teeth protection
- Concomitant drug therapy
- Short-duration procedure

Box 35.3 Anaesthetic considerations for patient transfer

- Familiarity with medical condition of patient needing transfer
- Familiarity with equipment
- Secure airway and vascular access
- Drugs to manage transfer safely
- Appropriate monitoring
- Transfer to a suitable member of staff at receiving hospital

surgery – resuscitation in the X-ray department in the middle of the night is to be avoided at all costs. Never underestimate the potential for problems in a CT scanner: it has been called the ‘doughnut of death’.

Recently, with the advent of the subspeciality of interventional radiology, more complex and complicated procedures are being undertaken in remote sites. Often these procedures take many hours, blood loss may be excessive and transfer to the main theatre recovery area can be complicated and fraught. Anaesthesia for patients undergoing MRI is highly specialised and requires MRI ‘safe equipment’ only, as unsafe metallic equipment may become catastrophically dislodged at high speed.

Anaesthesia for Cardioversion

Cardioversion is often undertaken in the coronary care unit, where appropriate monitoring is usually available. This avoids the risks of moving a sick patient. Any subsequent arrhythmias are usually managed by the cardiologist. The minimum requirements for safe anaesthesia must be met. Often the procedure is of short duration and the cardioversion occurs under the induction dose of the intravenous agent.

Inter-Hospital Transfer of Patients

The monitoring requirements of patients undergoing anaesthesia were discussed in Chapter 10. Similar requirements must be met when patients are transferred. Additional anaesthetic considerations are shown in Box 35.3.

Inter-hospital transfer of patients should only be undertaken by experienced anaesthetists after training. Patients should be physiologically stable before transfer. Any patient who may require tracheal intubation should have this undertaken prior to transfer – it is very tricky to undertake this at 40 miles per hour en route to the new hospital. Ambulances often contain ventilators and suction equipment that are different from those found in hospitals. Familiarisation with these is essential before the patient is moved. Tracheal tubes and intravenous cannulae must be secure. The correct drugs for the duration of journey must be available: this includes oxygen and drugs for the maintenance of anaesthesia, paralysis and resuscitation must be available. A ventilated patient requires the same monitoring as in theatre or the ICU. Always have an AMBU bag available.

Conclusion

Beware of anaesthesia in some distant outpost of the hospital. If you have any doubts about the safety of the procedure, then insist that the patient is moved to the main operating theatres. Any inconvenience that this may cause is trivial when compared with the occurrence of an anaesthetic disaster.

Section**4**

Walking the Walk (and Talking the Talk)

An eminent statesman of world repute always travels with his personal doctor. That doctor is not a physician, but an anaesthetist. This politician has deduced that, if he becomes acutely ill or injured, the best person to immediately take care of him is an anaesthetist.

The same argument applies to hospitals in the twenty-first century where the experience of trainee anaesthetists is of value outside the operating theatre. As part of your training you will work in ITU/ HDU, assess sick patients on wards, participate in pain teams and increasingly manage pre- and postoperative care. You will also be called to the emergency department to assist in resuscitation – skills in airway management and vascular access are critical here.

Go forth from the operating theatre with confidence and use your knowledge and skills to identify, diagnose and treat sick patients. This work may be called critical care/intensive care, perioperative medicine or just plain old anaesthesia. The label does not matter, walk the walk and talk the talk round the hospital. In the words of the famous T-shirt – ‘just do it’.

Management of the Patient in the Recovery Area

At the end of surgery, the patient is usually transferred to the recovery area or Post-Anaesthesia Care Unit (PACU) and is looked after by trained staff. Occasionally the patient needs to go to HDU/ICU, and this should be planned whenever possible. Last-minute requests for beds in HDU/ICU are deservedly unpopular. Do not transfer the patient from theatre if ventilation, circulation and neuromuscular function are inadequate. The operating theatre/anaesthetic room is a much safer environment for the patient than a long hazardous journey to recovery. Exhortations by surgeons and theatre staff to move the patient should be ignored until the patient is stable physiologically. All patients must be transferred from theatre to recovery breathing oxygen. Most recovery units accept patients with supraglottic airway devices (SADs) still in situ, but tracheal tubes should only be left in place in exceptional circumstances (usually when intermittent positive pressure ventilation (IPPV) is necessary).

A full handover to the recovery staff is essential with patient comorbidities, and the anaesthetic technique used (drugs, fluid, analgesia etc.) and any complications. Just saying it's a 'Lap Chole' is inadequate! The anaesthetist must also explain what specific care is required in addition to the routine observations. The patient remains the responsibility of the anaesthetist during this time, and an anaesthetist must be available immediately should any problems arise. If you have any doubts about leaving the patient in the care of the recovery staff, then you must remain with the patient. This is essential if the patient is still intubated. Your duty lies with the patient you have just anaesthetised – the remaining cases have to wait.

The equipment and monitoring facilities in the recovery room should be the same as in a fully equipped operating theatre.

The objectives of care in the recovery room are shown in Box 36.1. Most units have guidelines on routine monitoring in the recovery area, and you must be familiar with them. One member of staff per patient is mandatory in the early postoperative period. Essential monitoring consists of careful clinical observation, and regular measurement of heart rate, arterial pressure, respiration and oxygen saturation. These measurements must be taken at least every 5 minutes after major surgery, but at intervals of 15 minutes following routine minor surgery. In most units 'routine postoperative care' means recording the vital signs every 15 minutes. It may be desirable to monitor the patient by means of invasive techniques, such as arterial and central venous cannulation, and suitable equipment should be available in the recovery area.

Box 36.1 Main objectives of care in the recovery area

- Assessment of conscious level
- Management of the airway
- Pain control
- Essential monitoring and observation
- Treatment of nausea and vomiting
- Management of shivering
- Temperature control
- Care of intravenous infusion
- Observation of surgical wound drainage
- Observation of urine output
- Oxygen therapy

Box 36.2 Causes of early postoperative hypoxaemia

- Hypoventilation
 - airway obstruction
 - central respiratory depression
 - respiratory muscle weakness
- Ventilation/perfusion abnormalities
- Increased oxygen consumption
 - Shivering (for management see Chapter 20)
- Impaired response to hypoxaemia
- Decreased oxygen content
 - low cardiac output
 - low haemoglobin values

Oxygen Therapy

Oxygen therapy is often given routinely in the postoperative period, as hypoxaemia is an inevitable consequence of major surgery. The main causes of early postoperative hypoxaemia are shown in Box 36.2. However, hypoxaemia can persist for several days.

Diffusion hypoxia is a transient phenomenon that occurs at the end of anaesthesia when nitrous oxide is replaced by air. If nitrous oxide has been used, it enters the alveoli from the blood very rapidly. Because nitrogen is much less soluble than nitrous oxide, expired volume exceeds inspired volume, and there is a dilutional effect on oxygen in the alveoli.

The main causes of early postoperative hypoxaemia are a degree of airway obstruction, central respiratory depression usually caused by opioids and respiratory muscle weakness resulting from inadequate reversal of neuromuscular blocking drugs. Remember that any patient with any degree of respiratory depression (with a raised PaCO_2) will have a reduced

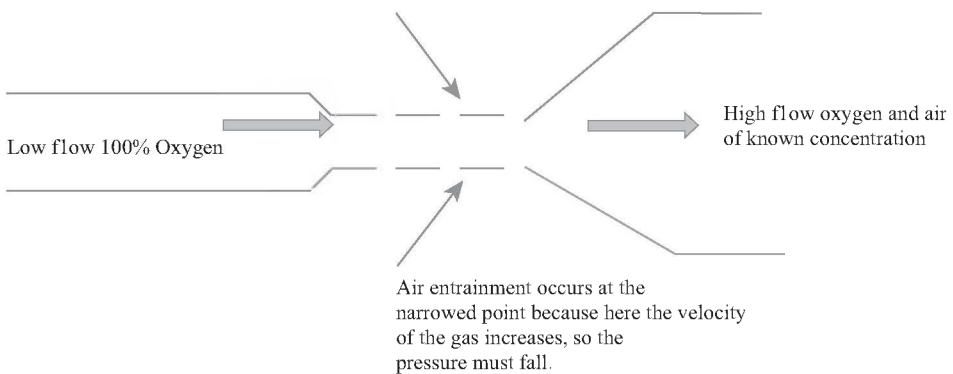


Figure 36.1 The Venturi effect

P_{AO_2} (and therefore P_{aO_2}) whilst breathing room air, as described by the alveolar gas equation :

$$P_{AO_2} \propto F_{IO_2} - (P_aCO_2/RQ)$$

Ventilation or perfusion abnormalities can arise after prolonged general anaesthesia and are exacerbated by factors such as obesity and pulmonary disease. Even very low concentrations of volatile anaesthetic agents impair the ventilatory response to hypoxaemia.

Oxygen is administered usually by a mask, either a fixed-performance or variable-performance device.

Fixed-Performance Oxygen Masks

These masks provide an accurate inspired oxygen concentration that is independent of the patient's ventilation because the flow rate of fresh gas delivered is higher than the patient's peak inspiratory flow rate (usually around 30 L/min). They work on the Venturi effect, of High Air Flow with Oxygen Enrichment (HAFOE). Air is entrained in oxygen by means of the Venturi principle to provide accurate concentrations of 24%, 28%, 35%, 40% and 60% oxygen, depending on which mask is used. The flow rates of oxygen required for these concentrations are written on the side of each mask. Such masks, for example the Ventimask, are expensive but are indicated when a precise concentration of oxygen needs to be given, such as in chronic obstructive lung disease. Following routine anaesthesia, cheaper, variable-performance masks are used.

Variable-Performance Oxygen Masks

Variable-performance masks, such as the Hudson mask, depend on the patient's inspiratory flow rate, the oxygen flow rate and the duration of the expiratory pause. Nasal cannulae function in a similar way. If a patient is breathing normally then an oxygen flow of 4 l/min will provide an inspired oxygen concentration of about 40%. If necessary, this can be checked with an oxygen analyser.

If an inspired oxygen concentration of more than 60% is required, it cannot usually be given by a disposable oxygen mask. An anaesthetic face mask is necessary.

Box 36.3 PACU problems delaying discharge

- Hypotension
 - common causes
 - bleeding and/or inadequate IV fluids
 - regional anaesthesia – epidural or spinal
 - left ventricular failure
 - vasodilation on rewarming
 - treatment: iv fluids (colloid) $\pm$ vasopressor
- Hypertension
 - common causes
 - pre-existing hypertension
 - pain
 - anxiety (secondary to inadequate reversal)
 - treatment: vasodilator, analgesia, reversal drugs
- Pain
 - consider the use of a variety of different drugs (multimodal analgesia) including
 - paracetamol IV
 - NSAIDs IV and PR
 - opioids (one route only)
 - local anaesthetics (top up epidural or nerve blocks if indicated)
- PONV
 - Treatment: Multimodal antiemetics
- Hypothermia
 - Treatment : Active warming
- Continued sedation
 - Treatment: None – just wait!

Calls from Recovery

You will often be called to recovery to assess patients. In addition to the immediate problems such as airway obstruction and failure to breathe (see Chapter 20), the difficulties summarised in Box 36.3 are common and delay discharge of the patient to the ward.

Finally, recovery staff may chase you to complete inadequate anaesthetic charts and prescriptions for postoperative intravenous fluids, analgesics, antiemetics and oxygen. Their attention to detail may save your patients, your anaesthetic colleagues and the hospital legal department from major problems. Listen to their concerns, smile and do the needful.

Discharge

Criteria for discharge from the recovery room are becoming common. The main points of anaesthetic relevance are shown in Box 36.4.

Box 36.4 Typical criteria for discharge from recovery

- Patient awake and responds appropriately to commands
- Upper airway patent and reflexes present
- Respiration and SpO₂ satisfactory
- Cardiovascular stability
- Pain control adequate, not vomiting
- Normothermic
- Analgesics, antiemetics, IV fluids, oxygen prescribed
- Other drugs also prescribed, e.g., thromboprophylaxis and antibiotics

Conclusion

The care of the patient in the recovery room remains the responsibility of the anaesthetist, who must be available to deal with any complications that may arise. The anaesthetist is also responsible for the discharge of the patient from the recovery area to the ward, and increasingly this is a formal, documented procedure. Remember that the recovery room is a good refuge for patients who need resuscitation before surgery – the staff are usually on your side.

Postoperative Analgesia

Pain is a subjective response to noxious stimuli, and patients vary greatly in their need for analgesia after surgery. For example, the amount of morphine requested post-operatively varies tenfold after the same operation. Analgesic regimens must take into account this unpredictable response. Acute pain teams are a popular development in anaesthetic practice and have drawn attention to past failings in the provision of adequate postoperative analgesia. The advantages claimed for good analgesia are shown in Box 37.1.

There are numerous analgesics available, working at different areas of the pain pathway. The principal analgesics include:

- (1) Non-steroidal anti-inflammatory drugs working by blocking cyclooxygenase (COX) and thereby reducing the production of inflammatory mediators.
- (2) Paracetamol. Its mechanism of action is probably centrally mediated.
- (3) Opioid drugs working by binding to various opioid receptors found within the nervous system including the spinal cord and the brain as well as in the gut.
- (4) Local anaesthetics can be effective throughout the pain pathway, for example a laparotomy can have analgesia provided from infiltration, various abdominal wall blocks (e.g., rectus sheath), or neuraxial blocks (Chapters 32–33).

There are many other described methods used to provide pain relief too. This include corticosteroids, ketamine, magnesium, gabapentinoids, alpha 2 agonists and non-pharmacological methods such as acupuncture and TENS. These methods vary in efficacy from moderately useful to moderately useless.

‘Multimodal Opioid Sparing Analgesia’

The underlying principle here is to minimise the amount of morphine required to decrease its unpleasant side effects, such as respiratory depression and nausea and vomiting – the concept of opioid sparing – by the concomitant use of other drugs working by different mechanisms. Some enthusiasts claim great success for opioid-free analgesia, which patients are often less enthusiastic about.

The humanitarian and psychological advantages of good analgesia are obvious. Pain, especially after abdominal surgery, can lead to deterioration in respiratory function from a reduction in ventilatory capacity and an inability to cough. Pulmonary atelectasis and infection are more likely. Pain causes tachycardia and hypertension, and this may exacerbate any existing myocardial ischaemia. Sweating and vomiting may accompany pain, and good analgesia makes early mobilisation and rehabilitation easier.

Box 37.1 Claimed advantages of good postoperative analgesia

- Humanitarian reasons
- Psychological reasons
- Fewer respiratory complications
- Fewer adverse cardiovascular responses
- Fewer autonomic complications (sweating, vomiting)
- Reduced 'stress response to surgery'
- Earlier mobilisation
- Less deep vein thrombosis
- Earlier return to normal lifestyle/work

Box 37.2 Factors influencing postoperative pain

- Age
- Sex
- Social class
- Preoperative analgesics (opioids, recreational drugs)
- Preoperative pain conditions (e.g., fibromyalgia)
- Anxiety and pain catastrophisers
- Understanding of surgery (education and expectation)
- Attitudes of staff
- Type of surgery
- Type of anaesthesia

Influences on Postoperative Pain

Postoperative pain is affected by many factors, including those listed in Box 37.2.

The elderly tolerate pain better than younger adults, and women are more stoical than men. People in social classes III, IV and V tolerate pain better than those in social classes I and II. Patients with a high preoperative neuroticism score experience more pain. A reduction in anxiety and patient education about the surgery have been shown to decrease postoperative pain.

The attitudes of staff and the adequacy of analgesia provided for other patients on the ward are also important. Staff who are reluctant, or have little time, to provide good postoperative analgesia adversely affect the patient's recovery. Fear of the side effects of drugs (e.g., addiction to opioids) is a totally unacceptable reason for the nursing staff not providing as much analgesic as required.

Many charts used after major surgery to record heart rate, blood pressure, temperature and respiratory rate also include pain scores (rest and movement), sedation scores, postoperative nausea and vomiting (PONV) scores and sensory and motor blockade, if an epidural or spinal is used. This enables staff to monitor the adequacy of pain relief. A newer and more logical way to assess pain is the functional activity scale (see Box 37.3) rather than a numerical pain score.

Box 37.3 Assessment of pain using the functional activity scale

Functional Activity Scale (FAS)

A	No limitation	Patient able to undertake the activity, without limitation due to pain
B	Mild limitation	Patient is able to undertake the activity but experiences moderate to severe pain
C	Significant limitation	Patient is unable to complete the activity due to pain, or pain treatment-related adverse effects

Box 37.4 World Health Organization (WHO) analgesic ladder

Step 1 (mild pain)	non-opioid analgesics such as paracetamol
Step 2 (moderate pain)	paracetamol, and a weak opioid (codeine, tramadol) +/- NSAID
Step 3 (severe pain)	paracetamol and a strong opiate (morphine) +/- NSAID

The most painful procedures are thoracic and abdominal but the pain usually subsides within 48–72 hours. It is thought that good analgesia, perhaps with the regular administration of analgesics during this time, prevents chronic pain after major surgery.

Methods of Postoperative Analgesia

An approach to the postoperative analgesic requirements of the patient must be considered during the preoperative visit (Box 37.4).

The importance of the preoperative visit and explanation to the patient of the procedures cannot be overemphasised. Consent for unusual routes of drug administration (e.g., rectal in the United Kingdom) must be obtained. For complex patients (e.g., those on high dose opioids), they should ideally be seen some weeks preoperatively to optimise pain medication.

Systemic Drugs

A simple approach to pain relief is provided by the WHO analgesic ladder, which demonstrates multimodal opioid sparing opioid analgesia:

Non-steroidal anti-inflammatory drugs (NSAIDs) are a valuable adjunct to pain relief after major surgery. However, they have several side effects which can limit their use (Box 37.5). Paracetamol, both intravenous and oral, has become the non-opioid analgesic of choice.

Morphine is the ‘gold standard’ opioid drug and is widely used for postoperative analgesia. Pethidine is used mainly in obstetrics (Chapter 34) but some advocate its use for postoperative shivering (Chapter 20).

All opioids have side effects, mostly unpleasant (Box 37.5). The traditional method of providing postoperative analgesia, by giving intramuscular morphine on request by the patient, has many drawbacks including intermittent analgesia and inadequate dosage. Opioids must never be administered by more than one route (e.g., by parenteral and epidural) as drug accumulation and thus respiratory depression/arrest can result. Only

Box 37.5 Main side effects of NSAIDs

- Gastric ulceration
- Decreased platelet aggregation
- Drug interactions (e.g., diuretics and serum potassium)
- Hypersensitivity
- Renal impairment
- Increased thrombosis risk in patients with cardiovascular disease for some NSAIDs

Box 37.6 Major side effects of systemic opioids

- Nausea and vomiting
- Sedation
- Cough suppression
- Opioid induced ventilatory impairment (OIVI)
- Euphoria
- GI problems: constipation, delayed stomach emptying, ileus
- Dysphoria and hallucinations
- Persistent post-operative opioid use (PPOU)

immediate release opioids are licensed for postoperative pain used and not sustained release preparations (including transdermal patches) as these are impossible to titrate to the patient's pain. Finally, make sure if patients are prescribed opioids to take home it is for a maximum of seven days. Long-term opioid prescriptions are a major factor in contributing to the opioid epidemic.

Common Analgesic Techniques

Patient-Controlled Analgesia (PCA)

Syringe pumps have been devised so that the patients (not visitors or members of staff) can administer their own analgesic opioids intravenously. There is no background infusion, so opioids are only administered after the patient has pressed the PCA button. An exception is in paediatrics where nurses deliver analgesia to children who are too young or otherwise unable to deliver analgesia themselves – Nurse-Controlled Analgesia (NCA) – and this is usually accompanied by background infusion.

The pumps must be safe and programmed to provide sufficient analgesia after major surgery (Table 37.1). Usually morphine is used (but other drugs such as fentanyl or oxycodone can be used) and occasionally other adjunct drugs are added to the morphine such as low dose ketamine. Once programmed they must be locked so that neither the syringe of opioid nor the controls are accessible. Patient-controlled analgesia does not mean patient-programmed analgesia. Careful explanation to the patient about PCA is essential for the success of the technique.

Table 37.1 Typical regimen for intravenous morphine PCA pump

Drug details	Regimen
Dose	50 mg in 50 ml sodium chloride
Concentration	1 mg/ml
Bolus dose	1 mg
Lock-out time	5 min
Hourly dose limit	12 mg

In theory, if patients become too drowsy they will not push the button and so will not receive excessive doses of opioids. Despite this, staff must monitor, at least hourly, the severity of the pain, the amount of analgesia used, the degree of sedation and the respiratory rate. If the respiratory rate is less than 10 breaths/minute or the patient is too drowsy, the infusion must be stopped. The opioid antagonist, naloxone, must be available and can be given in cases of severe respiratory depression, but it should be remembered that analgesia will also be reversed. Repeated small doses of naloxone may be necessary.

Regional Techniques

Local anaesthetic drugs can be administered as a single bolus, by intermittent injections, or as a continuous infusion. They can be given into the subcutaneous tissue around a wound (sometimes a wound catheter) into joints, abdominal wall (e.g., rectus sheath blocks), the pleural cavity and in the region of the spinal cord (epidural, spinal).

Opioids are often given via the neuraxial route, either in combination with local anaesthetics, or individually, to provide analgesia. Local anaesthetics have toxic side effects (see Chapter 16). The balance of possible complications versus benefits must be considered.

Miscellaneous

Both inhaled nitrous oxide and methoxyflurane (the latter no longer used as an anaesthetic) are unusual in that they have analgesic as well as anaesthetic properties. Thus Entonox (50% N₂O:50% O₂) or methoxyflurane (pentrox®) can be used to help alleviate the pain of short-lived procedures such as the removal of chest drains or in ambulances or the Accident and Emergency department. In dental surgery steroids reduce the inflammatory response, swelling and consequent pain.

Transcutaneous nerve stimulators and acupuncture are used occasionally as adjuncts to other analgesic techniques.

Conclusion

Many techniques are currently available to provide pain relief after surgery. Side effects are inevitable and patients must be nursed in the appropriate location to rapidly detect problems. Some of these, such as vomiting with opioids, can be distressing, others can be fatal (e.g., opioid overdose or high neuraxial blocks). It is essential that you see the effectiveness or otherwise of the chosen postoperative analgesic regimen and ask the patients for their opinions.

Recognition and Management of the Sick Patient

The anaesthetic trainee is often called to a ward to assess and initiate treatment of the ill patient. The correct diagnosis must be established, resuscitation started and the patient stabilised.

A patient who requires emergency surgery should ideally have full resuscitation and stabilisation before surgery. However, a balance needs to be struck between the benefits of restoring physiological normality and the dangers of delaying surgery. Often this judgement requires senior help. Principles of care are outlined in Box 38.1.

Sick patients are often in cubicles with other patients. Anything you say may be overheard, so avoid criticisms of care and insinuations of blame. Be professional and discreet.

Ward patients are observed and their recordings are subject to a trigger scoring system (National Early Warning Scores, or NEWS). The following six parameters are measured:

- respiration rate
- oxygen saturation

Box 38.1 Principles of care in the sick surgical patient

- Correct diagnosis – team approach
- Where to resuscitate
- Communication
 - address individuals
 - be heard
 - be understood
- Notify operating theatre and relevant staff
- Treat patient
 - oxygen therapy
 - intravenous fluids
 - urinary catheter
 - cardiovascular – invasive or non-invasive monitoring
 - gastric stasis – nasogastric tube (trauma, sepsis, diabetes)
 - analgesia
 - drugs – antibiotics, inotropes, diuretics
- Transfer of patient with full monitoring

- systolic blood pressure
- pulse rate
- level of consciousness or new confusion
- temperature

Normal recordings score 0 but abnormally high or low recordings score up to 3. High individual scores or aggregate scores trigger medical assessment – see Table 38.1.

Diagnosis

Do not assume that the diagnosis given by the ward staff is correct. Hypotension and tachycardia after surgery are more likely to result from hypovolaemia and haemorrhage than myocardial infarction. Similarly, an unconscious patient may have suffered a stroke, but other causes must be sought (see Box 19.7). Examine the patient yourself to confirm or refute the tentative diagnosis. A heart rate over 100/min is abnormal! A useful check list is:

- Haemorrhage and hypovolaemia?
- Cardiac – arrhythmias/myocardial infarction/failure?
- Sepsis – the great mimic?
- Pulmonary embolus?
- Iatrogenic – pneumothorax, epidural problems, PCA overdose?

Where to Resuscitate

Wards often have poor lighting, few staff at night and the drugs and equipment needed are usually unavailable. Attempts to resuscitate the patient in such surroundings almost inevitably waste time, and it is much easier to transfer the patient to a place where staff are familiar with invasive procedures. Suitable environments are the theatre recovery area, an anaesthetic room and the high dependency unit. If the patient is in the accident and emergency unit, it is usually safer to manage them there until stable. In particular tracheal intubation must always be undertaken with trained staff and appropriate monitoring etc. (just like any anaesthetic) and this inevitably means theatres or ICU.

Communication

Two situations commonly occur. First, you are left with no staff to help, and second, there are many people available and yet nothing is happening. In the first instance, get help; one knowledgeable and skilled assistant is ideal. In the second situation, take charge; you will probably be the best person to do so. When you want something to be done, address specific people, speak clearly and ensure you are heard and understood. Insist that the person reports back when the instruction has been fulfilled. Record events clearly, although this may have to be done later. If the patient needs to go to theatre urgently, inform theatre staff.

Treatment

Oxygenation is a priority. A suitable mask should be placed on the patient's face and the oxygen supply turned on. Wards often only have variable performance masks available, and an oxygen flow rate of 6 l/min is necessary to increase the inspired oxygen to about 50%.

Table 38.1 National Early Warning Score

Physiological parameter	Score						
	3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO ₂ Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO ₂ Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–94 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101– 110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1– 36.0	36.1–38.0	38.1–39.0	≥39.1	

NB SpO₂ Scale 2 is only used with patients who have hypercapnic respiratory failure) from RCP London)

Intravenous fluids should be given. Plasmalyte or Hartmann's solution are the fluids of choice if a crystalloid is required. Blood may be necessary if there is obvious haemorrhage (Chapter 13).

Appropriate monitoring should be established. If necessary, direct measurement of arterial pressure and central venous pressure should be undertaken (see Chapters 5 and 10). Fluid replacement is then guided by these intravascular pressures. Initially, a systolic arterial pressure of more than 100 mm Hg usually ensures that perfusion of the key organs is adequate. The adequacy of renal perfusion is often assessed by measuring urine output. A urinary catheter is essential for accurate measurement, and the output should be more than 0.5 ml/kg/h. Inotropic support may be required if an arterial pressure cannot be achieved after optimal filling of the circulation.

If sepsis is suspected give IV antibiotics. Do not merely prescribe them, administer them yourself immediately. Gastric stasis can develop rapidly in sick patients, and it may be necessary to insert a nasogastric tube. Analgesia may be required. Small bolus intravenous injections of morphine 1–2 mg are the safest method of achieving pain relief in sick patients.

An adequately resuscitated patient will be suggested by

- heart rate < 80/min
- respiratory rate < 18/min
- systolic pressure > 100 mmHg
- CVP > 5 mmHg and no increase on fluid challenge
- urine output > 0.5 ml/kg/h
- ABG base excess below -3 mmol/l
- blood lactate < 1.5 mmol/l
- Warm with good capillary refill

Transfer of Patients

Sick patients go on journeys round hospitals, and these trips are potentially dangerous. The patient must only be moved when suitable members of staff are available with appropriate monitoring. It is unacceptable to resuscitate a sick patient with full monitoring and then remove most of it for transfer. When moving the patient, guard carefully venous and arterial cannulae, catheters, drips, drains, and so on, so that they are not pulled out.

Be certain that staff will be available to help on arrival – this is a particular problem in radiology departments at night.

Conclusion

Rescuing sick patients from wards often falls to trainee anaesthetists because of their knowledge of resuscitation and technical skills. If in doubt, move the patient to a place where you have the necessary equipment and support.

Intensive Care (Critical Care)

Part 1

Many trainees are introduced to an intensive care unit (ICU) much earlier than a generation ago. It has evolved into a large speciality with a concomitant increase in bed numbers. In addition, ICU was once the day-to-day remit of an anaesthetic registrar with supervision (almost invariably by a consultant whose principal training had been in anaesthesia). Today, it is staffed sometimes by very junior doctors in their foundation years, registrars from a number of specialities and consultants who may have received their core training in specialities outside anaesthesia (e.g., medicine, Accident and Emergency). You will be exposed to ICU at an early stage of your training – perhaps even before anaesthesia itself.

In essence ICU deals with two major areas:

1. Recognition and diagnosis of a sick patient
2. Support for failing organs

The latter area is considered in Chapter 40.

ICU Definitions: Levels 1–3

The levels of care used (with level 0 defined as patients whose needs can be met on a normal ward) are shown in Box 23.8.

Somewhat confusingly, some hospitals use other terms such as high dependency (HDU) which is usually level 1 or 2, with ICU implying level 2 or 3 care. It would be convenient if all these levels of care were provided in a single place within any hospital; sadly this occurs rarely. There may be an HDU far removed from ICU (e.g., obstetric HDU). ICUs usually provide outreach services to review patients at an early stage and facilitate stabilisation and transfer to ICU, as well as seeing patients recently discharged from ICU.

Brief Pathophysiology Overview in ICU: Shock and Systemic Inflammatory Response Syndrome

Whilst there is no unifying process that encompasses the critically ill patient, there are nevertheless various concepts that help explain the diagnosis and management of these patients. ICU patients tend to have organ system dysfunction or failure, often starting with one organ and sometimes progressing to multi-organ failure. Moreover, the physiological impact depends on the reserve present within that system. For example, the same ‘renal insult’ may have minimal effect on a young adult, but a catastrophic effect on an elderly patient with coexisting renal impairment.

At the core of this pathophysiology is inadequate cellular oxygenation, which ultimately leads to anaerobic metabolism with biochemical markers such as a raised blood lactate

Box 39.1 How to optimise oxygen delivery

- Stroke volume optimisation with fluid therapy and then, if required, with vasoactive drugs
- Heart rate (and rhythm). Sinus rhythm at 80–90 beats per min is ideal
- SaO₂ – from simple oxygen therapy to complex mechanical ventilation strategies and even extracorporeal oxygenation
- [Hb]. The optimum level is debated often; over 80 g/l is considered adequate. If too high, blood viscosity may reduce cardiac output. Too low, then DO₂ falls and any haemorrhage, even relatively small, may prove fatal

value. This is often called shock, to be distinguished from its frequent use in films and television ('quick – he's going into shock, doctor').

The respiratory and cardiovascular systems are of major importance in delivering oxygen to the tissues (DO₂) and, remembering that oxygen carriage is determined by both % saturation of haemoglobin with oxygen (SaO₂) and haemoglobin concentration [Hb], there is a fundamental equation defining DO₂ (for simplicity we ignore dissolved oxygen):

$$DO_2 = \text{cardiac output} \times SaO_2 \times [Hb]$$

Cardiac output (CO) is the product of stroke volume (SV) and heart rate (HR), so the equation can be rewritten:

$$DO_2 = SV \times HR \times SaO_2 \times [Hb]$$

Thus there are four target areas to optimise and these are shown in Box 39.1.

DO₂ is approximately 1 l/min in a normal adult. Since oxygen consumption is only about 0.25 l/min, then 0.75 l/min of oxygen returns 'unused' to the heart. If the arterial SaO₂ is 100%, the returning (mixed or venous saturation SvO₂) would, therefore, be 75%. Often we estimate this figure from central venous oxygen saturation, with low levels implying poor cardiac output and thus increased extraction by the tissues. High mixed venous saturations may be due to an increased cardiac output, but may also result from widespread vasodilation (e.g., early sepsis) and opening of arterio-venous vessels, completely by-passing metabolising tissues.

Thus we have a rationale for assessing and targeting the factors that cause shock.

Systemic Inflammatory Response Syndrome and Sepsis

A secondary issue is the major inflammatory response that accompanies not only sepsis, but includes trauma, ischaemia and major surgery. Systemic Inflammatory Response Syndrome (SIRS) is used to describe the coexistence of two or more of the following as shown in Box 39.2.

Systemic Inflammatory Response Syndrome results from cytokine release and causes not only inflammation but also endothelial damage, with marked intravascular fluid loss and oedema (and changes in coagulation too). This can then be used to define both sepsis and severe sepsis and septic shock as shown in Box 39.3.

Box 39.2 SIRS criteria (two or more)

- Tachycardia (>90 bpm)
- Tachypnoea (>20 bpm)
- Changes in core temperature ($<36^{\circ}\text{C}$ or $>38^{\circ}\text{C}$)
- Changes in white blood cell count ($<4,000/\text{mm}^3$ or $>12,000/\text{mm}^3$)

Box 39.3 SIRS, sepsis and septic shock

- Sepsis = SIRS and source of infection
- Severe sepsis = sepsis with organ dysfunction/hypotension/hypo-perfusion
- Septic shock = severe sepsis with hypotension in spite of fluid resuscitation

Types of Patients

Anaesthetists usually transfer patients to ICU postoperatively and may think that this is the major workload of the unit. Although there are specialised ICUs in major centres (e.g., cardiothoracic, neurosurgical, burns and paediatrics) as well as coronary care units, the majority of ICU beds care for a varied patient population which includes the following:

- Trauma
- Medical conditions such as heart failure, pneumonia, stroke, epilepsy, diabetic coma, sepsis from any cause, thromboembolism
- Surgical conditions, not only immediately postoperative, but complications such as sepsis (again) from wounds, anastomotic breakdown, urinary and other catheter related infections, thromboembolism, organ failure (e.g., renal)
- Chemotherapy related problems, usually related to sepsis (again) and other effects of chemotherapy.

Early Treatment of the Sick Patient (See also Chapter 38)

The diagnosis of a critically ill patient may be self-evident (e.g., trauma) but in many cases there may be a subtle deterioration over time, which may go unnoticed for several hours (or longer). All hospitals now use an Early Warning Score (EWS) system, previously a Modified Early Warning Score (MEWS) and currently a National Early Warning Score (NEWS). These are reproducible physiological 'track and trigger' scores, so that sick patients who are deteriorating, or at risk of further deterioration, are identified along by recording various physiological components (Table 38.1). The charts are colour coded to assist (perhaps the less numerate) in the process.

Within ICU itself in the management of sepsis, another scoring system exists, which is more refined Sequential Organ Failure Assessment (SOFA) scoring. This scores the following:

- Respiratory parameters (oxygen requirements)
- Cardiovascular parameters (inotrope requirements)

Box 39.4 Management of sepsis in the first hour (the sepsis six)

- Blood lactate measurement
- Blood cultures
- Intravenous antibiotics
- Administration of oxygen
- Intravenous fluids 20 ml/kg (30 ml/kg crystalloid for hypotension or lactate ≥ 4 mmol/l)
- Urinary output measurement

- Platelet count
- Bilirubin
- Glasgow Coma Scale
- creatinine concentration and urine output

It is used to predict mortality and response to treatment (including trials). A much more simple quick SOFA score (qSOFA) is useful to predict mortality from sepsis and measures just three parameters:

- respiratory rate ≥ 22 breaths/min
- altered mental status (GCS <15)
- systolic blood pressure ≤ 100 mmHg

Another key area is arterial blood gas analysis, which should be performed in every sick or deteriorating patient, with the inspired oxygen concentration documented. Significant reductions in PaO₂ (Type I respiratory failure), rises in PaCO₂ (Type 2 or ventilatory failure), significant metabolic acidosis (base excess > 5 mmol/l) or lactic acidosis (> 3 mmol/l) all require urgent critical care review.

Sepsis is a common cause of many ICU admissions with delayed diagnosis significantly increasing morbidity and mortality. Indeed, it is a paradigm of ICU management. A number of high-profile campaigns (e.g., surviving sepsis) have highlighted these issues. These patients require not only prompt diagnosis, often aided by the MEWS score, but also urgent care, preferably within an hour of diagnosis. This care is shown in Box 39.4.

The sepsis six is sometimes called the 'six give and take', that is, three 'gives' (oxygen, fluids, antibiotics), three 'takes' (blood cultures, blood gases, urine output). In addition, if there are signs of organ dysfunction – hypoxia, resistant hypotension, oliguria, acidosis, coagulopathy – the patient will need prompt referral to ICU for organ support.

Conclusion

For the novice trainee, the ICU can appear a daunting place. It is full of sick patients with senior medical and nursing staff who appear to deal effortlessly with complex problems. Do not be intimidated, your anaesthetic skills will help you rapidly cope with these new challenges.

Intensive Care (Critical Care)

Part 2

Organ support is the cornerstone of clinical management for ICU patients, often buying time whilst natural recovery takes place aided by other therapies (e.g., fluid resuscitation, antibiotics). There are specific therapies, up to and including organ transplantation (e.g., liver, renal), for each organ.

Respiratory System

There are three key interventions which can be escalated in a deteriorating patient and reversed for a patient who is improving or weaning from ventilation:

- Low PaO_2 in Type 1 respiratory failure requires oxygen to be administered, using the minimum concentration to restore normal PaO_2 values.
- Non-invasive ventilation (NIV). Increasing levels of support can be provided with a tight-fitting facemask and include Continuous Positive Airways Pressure (CPAP), Bi-level Positive Airway Pressure (BiPAP) and Non-invasive Positive Pressure Ventilation (NPPV). These can be used to reduce PaCO_2 as well in Type 2 respiratory failure.
- Tracheal intubation and mechanical ventilation. This will very often dramatically increase oxygenation as well as reduce the work of breathing for patients (a significant factor for tachypnoeic and exhausted patients). A major focus is to minimise barotrauma and the use of low tidal volume ventilation is standard – 6 ml/kg of ideal body weight (IBW). Prolonged ventilation usually necessitates a tracheostomy.

For patients who are in extremis, other methods such as Extracorporeal Membrane Oxygenation (ECMO) are available at a few cardiothoracic centres.

Cardiovascular System

The two main areas are:

1. Fluid optimisation
2. Vasoactive medication

There has been a major move away from measuring pressures, such as central venous pressure (CVP), towards flow with the assessment of stroke volume and hence cardiac output. When stroke volume no longer increases with a carefully titrated bolus of a fluid challenge (e.g., 250 ml of crystalloid), if further increases in cardiac output and/or arterial pressure are necessary, inotropic support is required (Table 40.1). A useful target is a mean arterial pressure (MAP) of $>65\text{mmHg}$. In major cardiac centres the use of mechanical support for the heart may be used, often as a bridge before major surgery or transplantation.

Table 40.1 Cardiovascular drugs

Receptors	Actions	Examples
adrenergic $\alpha 1$	vasoconstriction	noradrenaline, high dose dopamine phenylephrine
adrenergic $\beta 1$	increased heart rate and increased contractility	adrenaline, dobutamine, dopexamine, moderate dose dopamine
adrenergic $\beta 2$	vasodilation	dobutamine
dopaminergic	splanchnic vasodilation	low dose dopamine, dopexamine
phosphodiesterase (PDE) III inhibitor	increased cardiac contractility, stroke volume, vasodilation	enoximone and milrinone
others, e.g., V1 receptors	vasoconstriction	vasopressin

Renal

The preservation of renal blood flow and perfusion pressure is key, as well as the avoidance of nephrotoxic drugs (especially non-steroidal anti-inflammatory drugs). Established renal failure results in acidosis, hyperkalaemia and fluid overload and continuous renal replacement therapy is used rather than intermittent haemodialysis. This requires a large double-lumen vascular catheter and some form of anticoagulation (citrate, heparin or prostacyclin).

Hepatic

Again the emphasis is on preservation of organ blood flow and cardiac output. N-acetyl cysteine is commonly used, but with little evidence to suggest significant benefit. Supportive care for other organs (encephalopathy and renal failure), as well as understanding and recognising coagulopathy and altered drug metabolism, are central to the management of these patients.

Neurological

Supporting the injured brain (e.g., after a head injury – see Chapter 42) involves intermittent positive pressure ventilation (IPPV) with mild hyperventilation to reduce cerebral blood flow, and avoidance of coughing and venous obstruction which increase intracranial pressure. Most sedation techniques (e.g., propofol) reduce cerebral oxygenation consumption, thus helping to minimise further cerebral insults.

ICU Drugs

A trainee may encounter some unfamiliar drugs in ICU.

- Cardiovascular

A number of drugs are available to support the cardiovascular system. In general, once fluid optimisation has occurred, inotropes are used to increase further cardiac output. Generally balanced crystalloids are used although some units prefer albumin solutions, even though the evidence for this is inconclusive. Vasoconstrictors are used to maintain mean arterial pressure in the face of a normal or high cardiac output but low systemic vascular resistance (e.g., sepsis or epidural analgesia).

Many drugs possess more than one effect. For example, adrenaline has mainly β_1 with weaker α_1 effects; noradrenaline has mostly α_1 but some β_1 effects. Dopamine classically has low, moderate and higher dose effects.

These drugs are very useful but have a number of serious adverse effects. Inadvertent bolus dosing can cause marked hypertension and tachycardia, conversely abrupt cessation of the drug can result in profound hypotension. Hyperglycaemia and lactic acidosis may also occur with some drugs, for example, adrenaline. In the susceptible heart (e.g., post infarct) there is a risk of tachyarrhythmias and increased myocardial oxygen consumption and therefore further infarction. Phosphodiesterase (PDE) III drugs, such as milrinone, may result in hypotension, and many of the drugs cause splanchnic vasoconstriction.

Arrhythmias that affect cardiac output need to be controlled. Normalisation of electrolytes (especially potassium and magnesium) is essential, before starting antiarrhythmic drugs such as amiodarone.

- Sedation (Usually for Patients on Mechanical Ventilation)

Intravenous infusions are used, typically propofol and midazolam or the newer agent dexmedetomidine. As in surgery, analgesia must be also administered if required (e.g., postoperative/trauma). Commonly used analgesics are remifentanyl, fentanyl and morphine. Analgesia is important for these patients, particularly if they are postoperative or have suffered trauma and they must not be sedated on propofol or midazolam alone. Attention must be paid to drug accumulation, particularly with organ dysfunction, and sedation scoring is used to help titrate the correct amount. A change of sedation and 'sedation holidays' are commonplace to reduce the risk of prolonged sedation which may delay weaning from ventilation.

Practical Approach to Patient Care

A systematic approach is mandatory, including clinical examination. Ward rounds from the coffee room looking at the patients' charts/computer screen are a very poor substitute. For the cardiovascular and respiratory system, the amount of support is reviewed and adjusted as appropriate. As improvements occur, weaning of support may be commenced. Renal assessment and fluid balance are charted and efforts made to prevent fluid overload – a common occurrence still. Assessment of the gastrointestinal system is required and feeding (preferably enteral) is started early. Hyperglycaemia is common and increases the likelihood of infection; it is treated with intravenous insulin. Microbiology is an important area and expert advice is required to treat infections and minimise the risk of hospital-acquired infections. In particular, vascular access (central and arterial cannulae) must be replaced regularly. Much of the care is standardised in

Box 40.1 Requirements before tracheal extubation after major surgery

- Low inspired oxygen requirements (<60%) to maintain good oxygen saturation
- Cardiovascular stability (even with inotropes/vasoactive support)
- Normal haemoglobin value and no haemorrhage/coagulopathy
- Normothermia
- Normal metabolic state (only minor derangements in pH, base excess and lactate)
- Good analgesia
- No problems with airway with no immediate need for tracheal reintubation

pathways called 'Care Bundles' which aim to ensure high-quality, evidence-based, consistent care. Documentation is mandatory.

The postoperative patient deserves special mention. After major elective surgery patients may go to ICU. Many patients undergo tracheal extubation before transfer if they have received good intraoperative care and are stable. The requirements for tracheal extubation after major surgery are shown in Box 40.1.

Prolonged surgery *per se* is not a barrier to early tracheal extubation. However some major surgery elicits a marked systemic inflammatory response syndrome (SIRS) response with fluid shifts so a period of ventilation and careful fluid titration is often wise. Emergency surgery is very different. The above goals are often more difficult to obtain and patients are ventilated until physiological stability occurs. Moreover, these patients are at increased risk of sepsis and organ dysfunction.

Communication

Good communication and thorough handover of patients during shift changes, or when entering or leaving ICU, is paramount. In addition, the patients and their next of kin need regular updates as well as support during what is a very stressful time. Documentation of the above is mandatory.

Point of Care Testing

Whilst laboratory and imaging assistance is crucial in managing ICU patients, some tests such as arterial blood gases (ABGs), thromboelastography (TEG) and ultrasound of the lung and heart can rapidly give information that enables treatment pathways to be instituted (see Chapters 9 and 14).

Transfer of Patients

Patients not infrequently need to be moved within the hospital (e.g., for scanning) or to other centres such as cardiac and neurological units, or for repatriation of an improving patient nearer to their home. This is clearly not a risk-free process and up to 20% of transfers have a critical incident. It is vital that all equipment and drugs are taken (often in transfer a 'grab' bag) to deal with any eventualities. Good monitoring and documentation is required. Remember to always have an AMBU bag to prevent you having to blow down a tracheal tube in the event of any gas failure.

Finally, if travelling outside of the hospital in an ambulance ensure you have your insurance in the case of a road traffic accident.

Unexpected ICU Emergencies

Expect the unexpected! Patients can accidentally be extubated or develop a pneumothorax and you must know how to find the equipment and deal with these eventualities. In particular, difficult intubations are more common in ICU and the staff assisting you will be less familiar with the process and the intubation equipment (which may be different to what you are used to in theatres).

After Intensive Care

Patients should be followed up once they have left intensive care to ensure that their progress is maintained. If this is not the case readmission may be required. In addition many patients may develop a post-ICU syndrome (PICS) with a number of physical, cognitive and psychological issues and may require prolonged input.

Ethics, Family Support and End of Life Care and Organ Donation

The care of patients in ICU may introduce some unfamiliar areas. The ethics of providing care, and the appropriate ceiling of care, for very sick patients in whom the likelihood for recovery is poor, who have a poor quality of life, incurable diseases (such as metastatic cancer), very poor physiological reserve or who have advanced directives always provokes great discussion. It is essential that this is a multidisciplinary team decision, with the patient (where possible) or the next of kin closely involved, with clear, detailed and contemporaneous note keeping.

The family will need good support, thorough and realistic explanation as well as advice to rest and recuperate themselves when not visiting.

The patient who has had brain death confirmed may be a candidate for organ donation, which will require further sensitive dealings with the distraught relatives.

Conclusion

A good ICU is the result of excellent teamwork, make sure that you play your part in supporting the team. You can learn much from experienced nursing staff, they are at the patient's bedside 24/7 – doctors are not!

Perioperative Medicine

Older anaesthetists saw the evolution of anaesthesia outside the operating theatre to formally encompass both intensive care medicine and pain medicine; both these subspecialties have separate specialist examinations in many countries.

More recently this concept has been expanded to include perioperative medicine, with the anaesthetist acting not just as an intraoperative physician, but as a perioperative physician. This concept represents the formalisation of a process that has been in place for many years as anaesthetists had a major input to the complete perioperative pathway starting from the decision to operate until the patient leaves hospital postoperatively. Many of these concepts are covered elsewhere in the book, and this chapter brings together and contextualises some of these themes.

It is widely recognised that high-risk patients (which can be related to their comorbidities or the surgery, or both) present a large burden, both social and economic. Perioperative medicine involves the co-ordination of the various strands of care, for example with a diabetic or renal physician. In addition, the development of ortho-geriatrics led by consultant physicians has improved the care of elderly patients with femoral neck fractures.

Preoperative Assessment

Once the decision has been made to operate, anaesthetists have a number of roles to play. Preoperative assessment clinics are usually run by nursing staff and subject every patient to a screening process face-to-face as an outpatient or online. It is a rather blunt tool, as a screening process is of limited value in picking up unexpected pathology. Nevertheless, a battery of questions, blood tests and electrocardiograms (ECGs) are routinely undertaken, some of which may pick up important pathology. Computerised reporting of ECG is useful; although generally over-reporting can pick up significant cardiac abnormalities. Higher risk patients are identified by the surgeon or the POA clinic and may be referred to a high-risk anaesthetic clinic (HRAC) to see a senior anaesthetist.

General advice such as weight loss, control of concurrent medical conditions (diabetes, hypertension and heart failure) and haemoglobin optimisation has been practised for years, with varying success. In particular, weight loss may take many months, and simply may not be a practical goal in a patient awaiting lower limb arthroplasty who will only be able to undertake very limited exercise. Occasionally, patients may have co-morbidities that can be improved by interventions before surgery such as percutaneous coronary intervention (PCI) for critical myocardial ischaemia.

High-risk patients may benefit from preoperative cardiopulmonary exercise testing (CPET). This subjects the patient to incremental exercise (usually on a cycle) and measures

not only cardiac variables but breath-by-breath gas exchange analysis via a mouthpiece from which a plethora of data is generated. Most useful are the anaerobic threshold (AT) – the point at which there is a detectable conversion from aerobic to anaerobic metabolism – and the maximum oxygen consumption ($\text{VO}_{2\text{max}}$ or $\text{VO}_{2\text{peak}}$).

The former is more widely used, not least because it is effort-independent. Moreover, there is evidence to show that fitter patients (AT of > 11 ml/kg/min) have a much lower risk than intermediate patients (AT of 8–11 ml/kg/min), who in turn fare better than the highest risk patients (AT of < 8 ml/kg/min). This information aids key decisions such as surgery or no surgery, the most appropriate surgery (e.g., perhaps a colonic stent rather than a resection) and patient specific perioperative care (e.g., ICU postoperatively).

Does training improve AT, and if so outcome? The answer to the first is yes, as all athletes know. The second area – exercising to improve outcome – is called prehabilitation (see chapter 11). It is a new concept but preliminary data show promise in elective surgery where exercise training preoperatively improved fitness and outcome. Preoperative chemotherapy may reduce fitness and again prehabilitation programmes may be beneficial, providing that any delay in surgery is not detrimental to the underlying disease process (e.g., cancer).

Some hospitals now have anaesthetists involved with the perioperative multidisciplinary team (MDT) as their knowledge is valuable in choosing the correct surgery and perioperative care for these patients.

Finally, there is recognition that patients, like athletes, do not benefit from excessive fasting before a major physiological insult (be it a competition or surgery). Giving patients fluids and more recently carbohydrate drinks, up to 2 hours before surgery, enables them to arrive in theatre hydrated and fed. The impact of other nutritional supplements, such as immunonutrients, on outcome is at present unknown.

Postoperative Care

Anaesthetists have usually had even less involvement in the postoperative period. This has changed particularly for patients undergoing major surgery. The traditional role of junior surgical trainees undertaking tasks for which they had little training and supervision has also changed. The general areas of postoperative care include those shown in Box 41.1.

A major role for the perioperative physician is the early recognition and management of complications, which have a marked impact on both short-term outcome and, perhaps more importantly, long-term outcome. Generally, complications following major surgery can be divided into medical and surgical, with the common ones listed in Box 41.2.

Box 41.1 Postoperative care requirements

- Thromboprophylaxis
- Oxygen therapy – how much and for how long?
- Analgesia – regular and as required (Chapter 35)
- Postoperative nausea and vomiting prophylaxis
- Antibiotics – not only on induction, but second doses may be needed intraoperatively or immediately postoperatively.
- Intravenous fluids – are they needed and if so for how long? (Chapter 6)

Box 41.2 Medical and surgical postoperative complications

- Medical
 - Respiratory failure/infections/aspiration
 - Cardiac failure/arrhythmias/infection
 - Thromboembolism
 - Renal failure/urinary tract infection
 - Delirium
 - Ileus
 - Sepsis
- Surgical
 - Surgical site infection/breakdown
 - Anastomotic breakdown
 - Ileus/gastro-intestinal obstruction
 - Pressure sore
 - Intra-abdominal collections/abscess
 - Intravascular cannula infections
 - Sepsis

There is some overlap; ileus and sepsis can be both medical and surgical. It is vital to recognise and treat sepsis early (Chapter 40).

Complications may be detected by the National Early Warning Score (NEWS) system, and there is then usually the involvement of the critical care outreach team (nursing staff) and medical staff. A decision can be made about further investigations, management and transfer, if required, to another ward such as HDU or ICU.

It is increasingly recognised that drinking, eating and mobilisation (DrEaMing) are key postoperative areas and anaesthetists have a part to play here, ensuring for example that patients have minimal postoperative nausea and vomiting (PONV), opioid usage, epidural and patient controlled analgesia (PCA) infusion duration as well as avoiding prolonged IV fluids, urinary catheters, nasogastric (NG) tubes and surgical drains. Many of the above will necessitate the patient being 'tethered' to the bed, unable to mobilise (and with increasing muscle weakness), at risk of IV fluid overload and lack of nutrition. Anaesthetists are more commonly seen on postoperative wards (e.g., on pain teams or outreach) and can work with surgical colleagues to facilitate the above.

Conclusion

Perioperative medicine is a natural development of preoperative assessment and postoperative care. It offers the anaesthetist a greater involvement in the management of the surgical patient. You will be able to explain to the patient that all postoperative complications are not the fault of the anaesthetic/anaesthetist – a common surgical excuse. However, as a speciality, we appreciate that our perioperative input may have a significant beneficial effect for some time into the postoperative period.

Management of Head Injuries

Anaesthetists are frequently involved in the management of patients with traumatic head injuries. A primary brain injury occurs at the time of the initial mechanical trauma. Although this is not treatable, it may have been preventable. An additional secondary brain injury begins immediately after impact. Inflammatory and neurotoxic processes result in raised intracranial pressure, decreased cerebral perfusion and ischaemia. This secondary injury will be worsened by further physiological insults such as hypotension and hypoxia. Consequently, you as the anaesthetist can reduce morbidity and mortality by preventing or treating the causes listed in Box 42.1.

General Considerations

Assessment of the patient should take place alongside resuscitation and begins with an ABCD approach.

- Cervical spine injury is commonly associated with a head injury. The neck should be immobilised by in-line cervical traction, or a collar, until radiographic or neurosurgical clearance is obtained.
- The airway may be compromised by a decreased level of consciousness, direct facial trauma or aspiration. Airway management must always be the priority. It should be cleared of blood and debris and protected by tracheal intubation if necessary. Indications for tracheal intubation are listed in Box 42.2.
- Hypoventilation occurs secondary to airway obstruction, decreased conscious level, spinal cord injury or thoracic trauma. Untreated this will result in hypoxia and hypercapnia which will worsen the brain injury.
- Hypovolaemia and hypotension rarely occur with an isolated head injury. Life-threatening chest and abdominal injuries should be looked for carefully. Control and treatment of these should take priority over transfer or neurosurgical intervention.

Box 42.1 Causes of secondary brain damage after trauma

- Hypoxaemia
- Hyper or hypocapnia
- Hypotension
- Hyperthermia
- Hyper or hypoglycaemia
- Increased intracranial pressure, e.g., coughing or straining

Box 42.2 Indications for tracheal intubation in the head-injured patient

- GCS ≤ 8
 - Significantly deteriorating conscious level (e.g., a fall in GCS of two points or more, or a fall in motor score of one point or more)
 - Hypoxaemia ($\text{PaO}_2 < 13 \text{ kPa}$ on oxygen)
 - Hypercarbia ($\text{PaCO}_2 > 6 \text{ kPa}$)
 - Spontaneous hyperventilation ($\text{PaCO}_2 < 4.0 \text{ kPa}$)
 - Bilateral fractured mandible
 - Copious bleeding into the mouth (e.g., from skull base fracture)
 - Seizures
- Neurological assessment is undertaken using the Glasgow Coma Scale (GCS) (Table 42.1). Localising signs and pupillary reaction should be sought and noted. Sequential changes in GCS score are a convenient way of assessing neurological progress. A GCS of less than 8 is considered a serious head injury and is often an indication for tracheal intubation.

Initial Management

Assessment of the airway is mandatory, and you should assume that the patient has a full stomach. Cervical stabilisation measures are often associated with difficult intubation. If intubation is deemed necessary, a rapid sequence induction technique must be undertaken. Thiopentone and propofol attenuate the rise in intracranial pressure that occurs with laryngoscopy, but care should be taken to avoid hypotension. For trauma patients, ketamine may be the best choice of induction agent, as the preservation of blood pressure will outweigh any theoretical concern about cerebral stimulation. Suxamethonium increases intracranial pressure transiently, but this is acceptable compared with the risks of an obstructed airway. A modified rapid sequence induction using rocuronium is also acceptable. Neuromuscular monitoring will provide reassurance that neuromuscular blockade has been achieved before intubation. A short-acting opioid will help to decrease the cardiovascular responses to laryngoscopy and intubation. Use a laryngoscope or videolaryngoscope with which you are familiar. If a difficult intubation is anticipated equipment used for difficult intubation and skilled assistance must be readily available. A nasogastric tube to empty the stomach may be inserted after tracheal intubation, but not if there is the possibility of a basal skull fracture. There is a risk of it passing through the skull defect and into the brain. A situation best avoided!

Management of Head Injuries

Hypoventilation causes hypoxia and hypercapnia; coughing and straining on a tracheal tube increases intracranial pressure. Adequate sedation is mandatory usually with a propofol infusion. Controlled ventilation to achieve a PaCO_2 of $4.5 - 5 \text{ kPa}$ and a PaO_2 of $> 13 \text{ kPa}$ is recommended to control intracranial pressure. Neuromuscular blocking drugs can be given, if required.

Hypotension results in reduced cerebral perfusion, and a mean arterial pressure of $> 90 \text{ mmHg}$ should be targeted. Adequate fluid replacement is essential; blood loss should be

Table 42.1 The Glasgow Coma Scale (GCS): neurological assessment

Response	Score
Best motor response	
obeys commands	6
withdraws from painful stimuli	5
localises to painful stimuli	4
flexes to painful stimuli	3
extends to painful stimuli	2
no response	1
Best verbal response	5
orientated	4
confused speech	3
inappropriate words	2
incomprehensible sounds	1
none	
Eye opening response	
spontaneously	4
to speech	3
to pain	2
none	1

replaced using blood products. Intravenous fluids used in brain injury should ideally be isotonic and glucose containing solutions avoided. When other causes of hypotension have been excluded, the use of inotropes or vasopressors such as metaraminol infusion should be considered to reduce the hypotensive effects of sedative agents.

Further management includes the use of intravenous mannitol (0.5 g/kg) or hypertonic saline (3–5 ml/kg of 3%), which are useful to decrease intracranial pressure transiently. Anticonvulsants may be necessary if seizures occur, and antibiotics are used prophylactically in patients with compound skull fractures. Tranexamic acid is recommended for patients with moderate or severe traumatic brain injury. Advice should be obtained from the regional neurosurgical centre.

Inter-Hospital Transfer

Patients who require neurosurgical intervention may need to be transferred to a regional neurosurgical unit and this may be a time critical transfer. Appropriate resuscitation and stabilisation of the patient before transfer is vital to avoid complications during the journey.

Patient management remains focussed on maintaining oxygenation and adequate blood pressure, and minimising rises in intracranial pressure. Short-acting drugs such as propofol,

Box 42.3 Guidelines for transferring head-injured patients

- Resuscitation and physiological stabilisation before transfer
- Escorting doctor of adequate experience
- Appropriate drugs and equipment for transfer
- Intubated patients require
 - sedation
 - paralysis
 - analgesia if indicated
- Use short-acting drugs to allow neurological assessment
- Monitoring to include
 - GCS, pupillary size and reaction to light, ECG, pulse oximetry, invasive blood pressure monitoring via an arterial line is preferable, capnography and urine output

fentanyl and neuromuscular blocking drugs are useful. Guidelines for transferring head-injured patients are shown in Box 42.3.

A detailed handover to the receiving anaesthetist at the neurosurgical centre is essential.

Conclusion

The anaesthetist has a major role in the management of the head-injured patient with the prevention of any secondary brain damage the initial priority. Guidelines recommend that transfer of a patient with a head injury to a neurosurgical centre should not be undertaken by a novice trainee. However, this may still occur. If you have any doubts about the airway and/or neurological state, tracheal intubation and ventilation should be undertaken before setting off in the ambulance.

Chronic Pain

Chronic pain is usually managed in the outpatient setting by a multidisciplinary team that includes not only anaesthetists but may also involve rheumatologists, neurologists and neurosurgeons, psychiatrists, clinical psychologists, specialist nurses, physiotherapists and occupational therapists. However, patients with chronic pain are often seen in perioperative settings. It is important you have an understanding of the pathophysiology and current management options.

Chronic pain is defined as pain that persists or recurs for more than three months. It is very common, affecting more than 30% of individuals worldwide. Chronic pain is now considered to be a disease in its own right. It can be categorised as nociceptive, neuropathic or nociplastic based on the underlying pathophysiology.

- **Nociceptive pain** – this is the most commonly encountered. It results from activation of neural pathways, secondary to actual tissue injury. It is typically described as an aching or throbbing pain. Causes include arthritis and most types of spinal pain.
- **Neuropathic pain** – this is caused by damage or disease affecting the somatosensory nervous system. It is often described as a burning, tingling or lancinating and is frequently associated with sensory abnormalities such as numbness, hyperalgesia or allodynia (pain due to a stimulus that does not normally provoke pain). Sensory abnormalities or skin changes may also be present. Common causes include postherpetic neuralgia, diabetic peripheral neuropathy or radiculopathy. Other causes include trigeminal neuralgia, post-amputation pain and multiple sclerosis.
- **Nociplastic pain** – this refers to pain resulting from the abnormal processing of pain signals without clear evidence of tissue damage or discrete pathology of the somatosensory system. It includes fibromyalgia and irritable bowel syndrome. These were previously known as functional pain syndromes.

The categorisation of pain will influence the investigations, treatment options and interventions and future prognosis. However, there is often considerable overlap in these different categories both within and between patients. Many pain conditions, especially those associated with cancer or the spinal column, do not fall neatly into one category.

Assessment of Pain

An individual patient's pain experience is shaped by a combination of both medical history and psychosocial factors. A comprehensive evaluation is essential. This should include:

- **Location** – get the patient to point to the location of their pain. Use pain maps to define the location and extent of pain.

- Intensity – both the severity of pain and changes over time. A standardised intensity rating scoring system is useful, e.g., verbal rating scale, visual analogue scale or numerical rating scale.
- Type – the characteristics of pain, e.g., aching or stabbing pain and any accompanying symptoms, e.g., numbness, weakness. Note factors that help alleviate pain, or which exacerbate it, e.g., rest or movement.
- History – precipitation or cause (if known), duration, previous investigations, surgery, interventions.
- Comorbidities.
- Use of prescribed, over-the-counter medications or other therapies and their effectiveness.
- Depression and anxiety.
- Impact on daily life, current activity and employment.
- Home situation – family, carers and significant others.

Classification of Chronic Pain

Chronic pain can be sub-classified to differentiate types of chronic pain syndromes:

- Chronic primary pain

Chronic primary pain is defined as pain in one or more anatomical regions, persisting or recurring for more than three months, and associated with significant emotional distress or interference with activities of daily life. Examples include conditions such as fibromyalgia, irritable bowel, non-specific low back pain or complex regional pain syndrome.

- Chronic secondary pain

Six other subgroups are defined where pain has initially developed as a symptom of another disorder or disease process. These include chronic cancer-related pain, chronic neuropathic pain, chronic secondary visceral pain, chronic post traumatic and postsurgical pain, chronic secondary headache and orofacial pain and chronic secondary musculoskeletal pain.

Management

The experience of pain is a consequence of a variety of biological, psychological and social factors and a wide range of pharmacological and non-pharmacological interventions are available. This means that it can be extremely challenging to determine the best treatment options for an individual patient. Patient engagement in the process is key and an interdisciplinary approach is recommended which focuses on the individual patient and uses a shared-decision model. Specialist pain clinics are available with expertise in managing pain. Referral should be considered when non-specialist management is failing. Some of the treatment options are outlined in Table 43.1.

Table 43.1 Suggested treatment options for different types of pain.
Remember that there is often overlap and many individuals have a mixed picture.

TREATMENTS	NOCICEPTIVE	NEUROPATHIC	NOCIOPLASTIC
PHARMACEUTICAL	NSAIDs Muscle relaxants SNRIs or tricyclic antidepressants Anti-rheumatic drugs (for inflammatory arthritis) Moderate opioids	SNRIs or tricyclic antidepressants Gabapentinoids Carbamazepine Capsaicin or Lidocaine patch (for regional pain) Tramadol Opioids	Simple analgesics SNRIs or tricyclic antidepressants
THERAPEUTIC INTERVENTIONS	Image guided blocks Neuromodulation	Image guided blocks Neuromodulation	
PSYCHOLOGICAL THERAPIES	Behavioural therapies	Behavioural therapies	Behavioural therapies
PHYSICAL THERAPIES	Manual therapies Exercise programmes		Exercise programmes

NSAIDs, non-steroidal anti-inflammatory drugs; SNRIs, serotonin-norepinephrine reuptake inhibitors

Pharmacological Management

Non-Opioid Agents

Various types of non-opioid medications are used to treat chronic pain. For neuropathic pain, both anti-epilepsy drugs and antidepressants are now first-line medications.

Gabapentinoids, especially gabapentin, have been shown to reduce pain scores in patients with postherpetic neuralgia and diabetic neuropathy. Pregabalin also appears beneficial. Carbamazepine has also been used successfully for neuropathic pain. However, side effects are common and the risks of these must be discussed prior to starting treatment.

In addition to their antidepressant action, tricyclic antidepressants and serotonin nor-epinephrine reuptake inhibitors (SNRIs) have useful intrinsic analgesic properties. Amitriptyline has been used successfully to treat patients with neuropathic pain and fibromyalgia. There is no evidence to support its use in patients with chronic low back pain but the SNRIs duloxetine and venlafaxine may have some benefit in this patient group. They can also be considered for diabetic neuropathic pain and fibromyalgia. Fluoxetine can be considered for fibromyalgia.

Topical lidocaine and capsaicin at high concentrations can reduce the hyperalgesia and allodynia that frequently accompanies neuropathic conditions.

Oral or topical non-steroidal anti-inflammatory drugs (NSAIDs) are used as first-line treatments for osteoarthritis and other inflammatory chronic conditions such as tendonitis. NSAIDs can also be beneficial in patients with non-specific low back pain. Paracetamol has potent antipyretic and analgesic effects, but little anti-inflammatory effect. It can be considered alone or in combination with NSAIDs in the management of pain in patients with osteoarthritis.

Opioids

The World Health Organization analgesic ladder provides useful guidance for advanced cancer pain. When pain is no longer controlled by simple analgesics or weak opioids, for example codeine, this suggests progression to strong opioids, for example morphine. Methadone or oxycodone are useful alternatives especially if morphine resistance develops or when opioid rotation is required. Either fentanyl and buprenorphine patches or diamorphine administered subcutaneously via a syringe driver can be used if the oral route is unavailable. Opioids with or without local anaesthetic agents can also be delivered via catheter techniques, for example epidural or intradural.

Tolerance to opioids resulting in diminishing pain relief can develop surprisingly quickly. Higher doses will then be required but with increasing doses come more side effects. In addition, sustained exposure can lead to pain pathways becoming sensitised and the development of opioid induced hyperalgesia. Although many patients with non-malignant chronic pain present to pain clinic taking long-term opioids, the evidence for their effectiveness in these patients is limited.

Misuse and addiction are major concerns with opioids. Abuse and misuse are more common than addiction, with rates of misuse estimated at 20–30%. There is also wide variation in analgesic response between individuals even those with the same pathology. Regular review and reassessment are recommended both for analgesic benefit and side effects.

Psychological-Based Interventions

Psychological therapies are playing a greater role in the management of patients with chronic pain. These can be offered as a sole intervention or in addition to pharmaceutical and other therapies. They can be undertaken on an individual basis or patients can attend group therapy. Psychological interventions include cognitive behavioural therapy, operant and biofeedback therapies, mindfulness and meditation. Multidisciplinary pain management programmes are now well established and have shown positive results. They are designed to help patients manage and live with chronic pain long-term rather than treating the pain itself.

Physical Therapies

Manual therapies encompass treatments such as manipulation and mobilisation by health-care practitioners, for example physiotherapists, osteopaths and chiropractors. These may be useful for short-term pain relief in patients with low back and neck pain.

Exercise programmes are now recommended for many patients with chronic pain especially chronic musculoskeletal pain.

Procedural Interventions

Minimally invasive procedures can be used for both diagnostic and therapeutic purposes, for example facet joint or epidural steroid injections and spinal cord stimulation for neuropathic back pain, although spinal cord stimulation is usually reserved for patients who have failed both conservative and pharmacological treatment options. Sympathetic blocks are sometimes used to enable physical therapy in patients with complex regional pain syndromes. Radiofrequency ablation can be used in the treatment of non-neuropathic pain such as facet or sacroiliac joint pain.

Conclusion

Chronic pain is very common and results in significant suffering and disability. Its underlying pathophysiology is extremely complex. A wide range of both pharmacological and non-pharmacological management options are available, but it can be challenging to determine the best strategies to optimise long-term outcomes for the individual patient. However, it is important to be aware of the available options and how to access appropriate specialist services.

Be the Best!

This final chapter deals with not just how to survive in anaesthesia, but on how to thrive in anaesthesia.

Self-Care Whilst Working a Demanding Schedule

Anaesthesia can be a very rewarding career, but it is also filled with stressful high-pressure situations coupled with the challenges that can arise with a long and competitive training programme. The arduous path of anaesthetic training is known for its demanding rotations comprising of busy rotas, working long days and nights and often hospital-hopping all over your country! Alongside, trainees are expected to build up their portfolios and study extensively to pass the speciality exams. Striking a healthy equilibrium can be tough and therefore requires remarkable resilience and support from those around you. In this chapter, we discuss how you can manage busy shift work whilst maintaining a healthy lifestyle.

Night shifts can be particularly tough, and you should find a way that helps you adapt to this change in sleep pattern. First and foremost, sleep is obviously the most important factor here, so ensure that you get enough sleep before, but also after, a night shift. Some trainees build themselves up to a set of nights by staying up the night before starting and then sleeping during the day, whilst others prefer to just nap the day before. Make sure you are adequately fed and hydrated before starting the shift and take (many!) refreshments with you for the shift. At the start of the shift, you should meet your team and ensure you know which consultant is on call for the night and how to contact them in case of an emergency.

Several hospitals have introduced the 'hospital at night' concept, in which all priority call members attend a meeting to state their role and discuss any patient or hospital issues that may arise during the shift. Not only will this allow you to meet some friendly faces (depending on the medical speciality) but also improve teamwork when challenges during the shift arise. This multidisciplinary meeting often includes Senior Nurse Practitioners (SNPs) and Advanced Nurse Practitioners (ANPs) along with medical staff, who can give information on the hospital status such as bed availability and staffing issues. You can use this as an opportunity to discuss any logistical issues and the medical team may want to make you aware of any unwell patients for whom they might require support or potential overnight theatre cases. Some hospitals have further 'hospital at night' meetings halfway through the shift, or even in the morning at the end of the shift to also allow for debriefing and handover.

Sometimes shifts can become extremely busy, leading you to forget that you haven't done basic things (such as going to the loo!), so make sure you get a break when

possible or ask a colleague to relieve you. During a night shift taking a 15–20-minute nap has been shown to improve alertness, therefore if clinical time allows, make sure you take a break and rest. Fatigue can lead to errors, so whilst it can be tempting to try and ‘power through it’, this can lead to serious mistakes so always ensure you are fit to work and well-rested.

Following good sleep hygiene, you may choose to use aids that can improve your sleep before, during and after night shifts, such as acquiring blackout blinds and minimising blue-light use, that is, of your phone or computer, ear plugs and eye masks.

The wellbeing of the anaesthetist is another very important point. As mentioned before, whilst an anaesthetist’s career can be very fulfilling and rewarding, it can also invite a wide range of personal and professional challenges. Looking after yourself is fundamentally key to ensuring healthy wellbeing. Time management will become your best friend – therefore making sure you organise your time well will allow you to enjoy life outside of work. Making sure you keep up with other interests is also critical, whether this is spending time with family and friends or being an enthusiastic Olympian, hobbies will keep you sane and in good spirits. Having a close network of important people in your life will also be important for the times you need a shoulder to lean on or an ear to moan in. Your network will be invaluable in everyday living, some may even be nice enough to do the grocery run for you or free babysitting! Most importantly, however, time management allows ‘me’ time and downtime for yourself with leisure activities, a respite from a demanding schedule or simply a spa and treat-yourself day.

Be aware that sometimes, no matter how well you try to balance your life and time, you may come up against difficulties and struggles (and this is OK and completely normal!). Dealing with it is essential. There is a full range of support networks and campaigns out there to support anaesthetists. There are wellbeing toolkits available, such as the one by the Association of Anaesthetists of Great Britain and Ireland (AAGBI), that can be of use. Most hospital departments offer support and counselling aid and are able to assist if an adjustment in working hours or schedule is required.

A trainee might find themselves in difficulty requiring additional support to overcome problems that may impede the completion of their training stage or programme. Early intervention and support for this is crucial and it is often the trainees but also clinical supervisors’ responsibility to detect warning signs of this. Clear and open communication with supervisors and colleagues ensures necessary adjustments can be made if required. Warning signs of a trainee in difficulty can vary from clinical knowledge gaps or missed attendance at departmental meetings to serious untoward clinical incidents. Patient safety may be at risk and evaluation for fitness to practice is imperative. Hospitals or regional training programmes may have specific policies on how to best approach this and there are support options available.

At this point, we would like to briefly mention the pitfalls of social media as its use is growing exponentially. It is extremely important to protect our patients (and your own GMC licence) by avoiding posting confidential matters online, as tempting as it may seem. This is especially true with platform X (formerly known as Twitter) as it is often used for educational purposes, such as sharing information, debating topics and making connections and networks. The educational content on these platforms is not peer-reviewed nor quality-controlled therefore always refer to other sources if in doubt.

The Green Anaesthetist

This chapter would not be complete without mentioning one of the biggest hot topics worldwide – climate change and global warming. It is highly likely you have already come across this in your lifetime and understand the issues surrounding this topic. The healthcare industry is responsible for 4% of the country's carbon emissions. Moreover, in the UK anaesthetic gases and nitrous oxide are responsible for around 2% of all NHS greenhouse gas emissions.

In this chapter we will briefly explain the basic science behind the problem, how anaesthesia affects this and lastly what you can do to play your part in reducing your anaesthetic carbon footprint.

Global warming is defined as a rise in the world's temperature which persists for a decade or longer. There can be several reasons for this to occur and in anaesthesia, these are mostly due to greenhouse gases and non-recyclable materials. How these affect the world is dependent on their potential to trap heat in the world's atmosphere, which can be measured as global warming potential (GWP). Common greenhouse gases include carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. Gases with a higher GWP lead to more heating potential. Anaesthetic gases and nitrous oxide play a significant part in this with nitrous oxide having a GWP 273 times that of carbon dioxide for a 100-year timescale. In addition, the problem is worsened as these gases become trapped within the atmosphere for several years. Desflurane is thought to have an atmospheric 'lifetime' of 14 years. The use of anaesthetic gases for one hour has been compared to driving a car – using sevoflurane and desflurane respectively equates to driving a car for 5–10 and 200–400 km. This has led to the ban of certain gases, such as desflurane for which NHS Scotland has been one of the first to remove it from its supply chain. Other countries are due to follow this initiative in the coming years with the European Union having formulated a proposal for its ban by 2026.

Most of our day-to-day anaesthetic equipment, drugs and gases have a carbon footprint, as they either require energy to run, produce waste or directly affect the environment. Single-use items such as facemasks and drug syringes are necessary for infection control and patient safety but lead to an extensive amount of waste even after a single anaesthetic.

There are alternative ways of delivering an anaesthetic such as the use of total intravenous anaesthesia (TIVA) or considering fully awake surgery using regional techniques. However, the first principle is always 'do no harm' and keep the patients safe which would trump any environmental concerns.

In the move towards greener anaesthesia, there are several ways in which a 'greener' anaesthetic can be delivered. First and foremost, modern anaesthetic machines and advances in equipment aid in providing a more controlled anaesthetic with lower anaesthetic gas requirements. Next, unsurprisingly, abstaining from the use of desflurane and nitrous oxide can have the largest impact. The amount of gases being used can be reduced by adopting a 'low flow' anaesthetic using a maximum of 1.5 L/min during maintenance. Ensuring a thorough anaesthetic machine check should ensure that scavenging is functional and that there are no leaks. Consideration of TIVA technique for your anaesthetic cases can also reduce the carbon footprint (however this comes at the expense of additional waste of the drugs and equipment packaging).

Additional measures such as the use of recycling bins and turning off operating room lights and equipment overnight when not in use can reduce energy expenditure.

Several healthcare environmental campaigns exist which are led by like-minded professionals who are striving to reduce the healthcare carbon footprint. Organisations such as Greener Healthcare and Sustainability Project (GHASP) provide tools and support for professionals on this matter.

The Training Process

Becoming an anaesthetist requires persevering dedication, strong commitment and meticulous attention to detail. Whilst they are often seen as mysterious figures looming in the operating room quietly completing crosswords and fiddling with the anaesthetic machine, anaesthesia often makes up the largest hospital speciality with nearly 20% of consultants being anaesthetists. Its training is often a lengthy path entailing a competitive entry to the training programme followed by extensive hands-on training, studying for (notoriously difficult!) exams and demanding rotations. The actual training programme itself differs by the individual country and is often accompanied by the individual country's own specialty examinations. In the UK, the Royal College of Anaesthetists (RCoA) sets out a seven-year training programme with an initial core stage lasting three years if full-time followed by another application process for the following years. This differs to other countries where the training is packed into a shorter time such as four years in the United States or five years in most European countries. There are critical progression points within this that trainees are expected to achieve including acquisition of specific competencies and exams. Similarly, the European Union of Medical Specialists (UEMS) lays out the competency-based training requirements for trainees across European countries. Within Europe, the European Diploma of Anaesthetics and Intensive Care (EDAIC) is a multilingual and internationally recognised qualification.

Anaesthetists require specific knowledge, skills and attitudes which are unique to this medical speciality, including the ability to work in high-pressure environments and situations, the use of advanced dexterity for complex procedures and detailed organisation and attention to drug doses and equipment to name a few. Moreover, anaesthesia is not a lone sport and good teamwork skills (as showcased by how friendly and chatty we are) are a necessity as well as the ability to step up as the leader during certain situations. Advanced knowledge and understanding of basic science, physics and pharmacology are a requisite for the anaesthetist.

As explained in previous chapters, anaesthetists can sub-specialise in specific fields, for example, perioperative medicine, obstetric anaesthesia, regional anaesthesia, pain and so on. Whilst these are part of most anaesthetic rotations, trainees may pursue additional training time by completing fellowships and work experiences. Depending on the country this may be incorporated into the overall training time or account as additional time spent in training. Competencies and exams may be required for some of these specialities such as the fellowship of the Faculty of Pain Medicine of the Royal College of Anaesthetists (FFPMRCA) in the UK.

Training in anaesthesia can, similarly to other specialities, sometimes seem like an endless journey and it is therefore important to reach out for support if required. The possibility to complete training at less than full-time has acquired popularity and made training more accessible and attractive. The application for this process may differ by department or region, often local advisors can offer support on these.

When training within a department clinical and educational supervisors tend to be the first call of support for a trainee and can also offer aid with the direction of training and projects.

The Anaesthetic Portfolio

An anaesthetist's commitment to speciality can be appreciated not only by their clinical work ethic but also in their academic portfolio. Keeping an electronic or paper-based portfolio up to date is as important as a regular Curriculum Vitae update. The portfolio can be split into different areas covering academic, management and leadership, research, audit and extra-curricular activities. See Box 44.1.

The portfolio should be able to demonstrate evidence of learning achievements, abilities and academic accomplishments. You should keep a logbook of all cases and procedures you undertake. The academic side may include additional degrees and certificates acquired prior to or during training. Specifically, postgraduate certificates and Masters in Medical Education, Perioperative Anaesthesia, Quality Improvement and Human Factors have gained popularity in recent years as most can be completed part-time whilst working full-time clinically. Completion of the anaesthetic speciality examinations also fall under this category and are frequently required at specific training stages. In the UK, the Fellowship of the RCoA (FRCA) Primary Examinations are required for eligibility to enter into the intermediate (Speciality Year 4) training stage.

Management and leadership skills are fundamental to the anaesthetist. Acquisition of these skills can be gained by attending specialised courses. Therefore, the attainment of managerial roles within a department can form part of this section. Teaching is commonly part of the anaesthetist's life varying from ad hoc teaching of medical students in the operating room to larger teaching events at courses or in universities. Simulation rooms are frequently a common place for anaesthetists and many courses, such as the Resuscitation and Life Support courses, require instructors and lend themselves a great opportunity for the keen anaesthetic teacher (and part actor).

The research and audit subsection speak for themselves, and trainees often find it difficult to get involved in research particularly, however, there are frequently unnoticed opportunities even within small hospitals. A starting point in research includes the attainment of the Good Clinical Practice (GCP) certificate which has become an agreed international standard for any clinician taking part in research. This can be completed online and

Box 44.1 Example layout of an anaesthetic portfolio

Index of an anaesthetic portfolio

1. Curriculum vitae
2. Certificates – Degrees & Qualifications
3. Awards
4. Courses
5. Audit & Clinical Governance
6. Research
7. Publications
8. Teaching
9. Presentations
10. Extracurricular activities outside of Anaesthesia

renewed every two to three years. Finding a research project or study to run can be a slightly more difficult step and depends on the opportunities available locally. Several hospitals have dedicated research departments which take part in larger local, national or even international trials and frequently require clinician support for consent or data collection. Similarly, societies or trainee-led networks may be offering Principal Investigator (PI) roles for studies they may be running.

Audits are a lot easier to come by and can also lead to Quality Improvement projects. Presentation of one's work is as important as undertaking it. This may be done by poster or oral presentation at meetings or conferences.

The scope of extra-curricular activities within a trainee's portfolio can be endless and commonly include activities outside of medicine which display leadership roles. These can include an active membership of a society or group to having exceptional roles or responsibilities such as trainee representatives.

Moreover, depending on the training programme, anaesthetists are often expected to give evidence of acquired competencies by completing supervised learning events (SLEs). In the UK, these include Multi-Source Feedback (MSF), Anaesthesia Clinical Evaluation Exercise (A-CEX), Direct Observation of Procedural Skills (DOPs) and Case-Based Discussion (CBD). For example, once you have mastered the skill of epidural insertion, your supervisor may be happy to complete a DOPs form. Similarly, case-based discussions can be used for learning and evidenced in the portfolio with reflective essays or other CBD forms. Evidence of acquisition of specific competencies may be required for different years in the anaesthetic training programme and evidence may therefore be stored in hardcopy or on a virtual learning platform. Feedback from colleagues is also incredibly important and will be reflected in the MSF, which may be part of an annual appraisal required for you to pass your training year. Therefore, always be kind to your colleagues, support them when they need your help and never forget to get your operating department practitioner a coffee!

Nurturing a trainees' portfolio can be a tough balance whilst working a relentless shift pattern, therefore time management for these activities is critical and often departments will support trainees in their involvement in projects and teaching.

Electronic Patient Records

The shift towards paperless digitalisation of medical records is another important area. Several hospital trusts have seen the digital transformation of medical records to a virtual platform, and this has majorly changed the way we work and provide care, especially in anaesthesia where writing an anaesthetic chart is common practice and keeps the anaesthetist busy throughout the case (together with sudoku and crosswords obviously). Electronic Patient Records (EPR) have been designed to replace paper-based notes and records and have enabled smoother and patient-centred care. In our speciality, this has the added benefit that technology has allowed us to link up our equipment to these platforms allowing real-time and accurate recording of notes, such as vital signs and oxygen or volatile use. It also has the added benefit of allowing communication with other healthcare professionals and easy review of past medical history and recent investigations and specialist appointments.

If you work in a trust that uses EPR, it is your highest priority to ensure you have done the required training and have your access password and card prior to starting your rotation. Your access card is extremely precious and losing it may put patient data at risk,

therefore keep it safe and always on you at work. Of course, you would also want to know which paper forms to use in case of system failure or even cyberattack!

Once starting your list, you should be able to log into your hospital computer system and EPR platform in order to view your patient list for the day and review their notes prior to an in-person assessment. Commonly, EPR allows you to record your anaesthetic assessment and you are able to view important health information about the patient and previous clinic reviews, such as preoperative assessment. Once recorded, other clinicians can review your recorded entry which can be particularly useful if you are working with a supervisor or colleague. Once in theatre, EPR requires a working computer to be connected to the anaesthetic and monitoring machine. Prior to starting the case you would insert your card and password and start a new anaesthetic case which would trigger the system to start recording data from the machine. Given drugs doses and events that may occur during the case need to be entered separately and timed accordingly.

Whilst the downside of EPR includes the requirement of working computers and EPR platform availability which can be linked to cost and logistical issues, there are several benefits linked to its use. In our field it allows anaesthetic information to be gathered peri-, intra and postoperatively using concise and accurate documentation. Some EPRs allow for standardisation of notes by using prefilled information or text-box type data for parts of records such as the preoperative airway assessment. Despite all its added benefits ensure you always check your recorded entries to confirm it is all correct prior to saving it!

Preparing for Meetings

It is commonplace to be asked to present during departmental or hospital-wide meetings such as a morbidity and mortality (M&M) meeting or journal clubs as an anaesthetic trainee and it is important you know how to prepare yourself for these. It is mandatory for hospitals to run M&M meetings so it can be a great opportunity to practise some presentation skills and complex patient workup. Moreover, these cases often allow for subsequent learning or even quality improvement changes to be introduced which you could take part in and have a leading role. Learning from real cases can be extremely powerful and these meetings often also allow for interesting discussions, whilst of course always involving coffee (especially in the world of anaesthesia!).

M&M presentations tend to focus on a patient case or incident and usually follow a systematic thorough review with some outcomes and action plans. There are several templates that can be used to help you for one of these meetings such as the one provided by the Royal College of Surgeons (RCS). The presentations tend to be rather structured involving initially a factual presentation of the case and what happened, followed by an analysis and learning points. Often evidence-based knowledge and evidence can be used and researched to aid the outcomes and possible need for change in clinical practice if required. When dealing with an interesting case clinically, it may be useful to do a case discussion with a colleague or write a reflection on it, in case it might come in handy for a presentation.

Journal clubs on the other hand can be very department-specific but still often remain a frequent occurrence and opportunity for trainees to present and critique papers, and more importantly, pick up up-to-date knowledge which may alter clinical practice even! These are slightly different to M&M meetings in the way that they focus on a selected scientific article, which gets presented, analysed and critiqued. Similarly, there are several templates and checklists available that you can use. The Critical Appraisal Skill Programme (CASP)

website can be a great starting point and allows you to download study-type specific checklists which you can use for your appraisal. Choosing an article can sometimes be the more difficult task but you can use a variety of approaches. You should pick a topic of your interest which is relevant to the field and interesting and may have a controversial aspect. This will allow for interesting discussions and again more coffee time. Having a browse through some high-impact online journals such as the *British Journal of Anaesthesia* (BJA), *Anaesthesia*, *Anaesthesiology*, *Anaesthesia & Analgesia* (A&A) and so on usually leads to a good find! As always, anaesthetists are known to be extremely friendly and approachable (in most cases!) so if in doubt ask an experienced colleague for some advice or support.

Useful Websites

Both the Royal College of Anaesthetists and Association of Anaesthetists of Great Britain and Ireland have a large amount of information and are worth a visit on a rainy day: www.rcoa.ac.uk/ and <http://anaesthetists.org/>.

If you need information on pain medicine visit the RCOA website, and Intensive Care information is at the Faculty of Intensive Care Medicine (www.ficm.ac.uk/) and The Intensive Care Society (<http://ics.ac.uk/>).

Other areas:

Airway

DAS website for algorithms: https://das.uk.com/guidelines/das_intubation_guidelines.

Open Airway – great resource for techniques and equipment and endorsed by the University of Capetown: <https://openairway.org/>.

Resuscitation

www.resus.org.uk/library/iresus

Ultrasound

www.nysora.com/introduction-ultrasound-guided-regional-anesthesia/

<http://pie.med.utoronto.ca/POCUS/index.htm>

Anaesthetic Equipment

<https://anaesthetists.org/Home/Resources-publications/Guidelines/Checking-Anaesthetic-Equipment>

Wellbeing Support

RCOA website: www.rcoa.ac.uk/membership/resources/wellbeing-hub

AAGBI wellbeing initiatives and contacts: <https://anaesthetists.org/Home/Wellbeing-support>

Needing a Good Review on a Specific Topic?

BJA education (the RCOA CPD journal): www.bjaed.org/

And Finally . . .

If you have read this book you have the basics of safe anaesthetic practice. You will have difficulties and make mistakes – we all do. If you do not have problems then either you are not working hard or you are not being honest. Discuss your problems with other anaesthetists, never be afraid to ask for help (we still do) and try not to keep making the same mistake! If in doubt, keep it simple. A secure airway and good venous access are the key to safe anaesthesia.

Enjoy life – you have joined a great specialty.

Anaesthetic Aphorisms

If you cannot be bothered to read all the other chapters then the following aphorisms will teach you a lot about the safe practice of anaesthesia. We thank our anaesthetic colleagues, past and present, for their help in compiling this list of epigrams that includes wisdom, witticism and a large helping of the obvious.

General

- Never start an anaesthetic until you have seen the whites of the surgeon's eyes (despite the WHO checklist they still disappear).
- Always pee before starting a list.
- If you are feeling tired the three S's is a good reviver – a shit, a shave and a shower (politically incorrect, but we do not know the female equivalent).
- ABC of anaesthesia – always be cool, always be cocky!
- ABCD of resuscitation – arrive, blame, criticise and depart.
- Remember KISS – keep it simple, stupid.
- Anaesthesia is 'awfully simple' but when it goes wrong it is 'simply awful'.
- Always look carefully at previous anaesthetic charts.
- If in doubt, ask for help. There is no place for arrogance in anaesthesia.
- First rule of anaesthesia – if there is a chair in theatre, sit on it.
- Preoperative assessment – always find out who is doing the operation, what time it is happening and where the patient is going after surgery.
- Accidents are funny things. You don't know they are happening until they happen (A. A. Milne). Stay vigilant.
- Never panic. This applies particularly when the patient is trying to die and you have no idea why.
- Where there is cyanosis there is life – just!
- 99 per cent of anaesthetics is dead easy. 1 per cent is easy dead!
- Needles go into blood vessels but around nerves.
- No coffee, no gassey.
- 'No' is a complete sentence.

Airway

- If in doubt, take it out. This applies to tracheal tubes and many other things in life.
- There are three things to respect in anaesthesia – the airway, the airway and the airway.

- When all else fails, disconnect the catheter mount and blow down the tracheal tube – we have all had to do it.
- Careless ‘torque’ costs lives – don’t let breathing tubes kink.
- The laryngoscope is a tongue retractor, not a tooth extractor.
- Nobody dies from failure to intubate the larynx, they die from failure to ventilate and oxygenate.
- The expired gas contains no carbon dioxide when you ventilate the stomach.
- Fix tracheal tubes as if your life depended on it – the patient’s life does!
- The first five causes of sudden hypoxia in an intubated, ventilated patient are the tube, the tube, the tube, the tube and finally the tube. The tracheal tube may be dislodged, disconnected, blocked or kinked, or the cuff herniated.
- If you anticipate a difficult airway, premedication with a drying agent is useful.
- In patients with a potentially difficult airway always have a plan B before starting anaesthesia.
- If you do have a problem with the airway, document it carefully for the next anaesthetist.
- Beware of patients with a beard – a receding chin may lurk beneath (this is strongly denied by one author).
- ‘Sniffing the morning air’ position for tracheal intubation can be described as the position of the head when taking the first sip from a pint of beer.
- The tip of a gum-elastic bougie can be bent after warming with hot tap water. If you try to bend it when cold, it will snap.
- Remember the humble nasopharyngeal airway. It is useful in patients with poor mouth opening, loose teeth and expensive dental work.
- If an intubated patient tells you the tube is in the wrong place they are always right!

Cannulation

- Always keep the giving sets on the appropriate side of the patient (left arm, left side). If you don’t, think what will happen when you move the patient – one out, all out.
- Use a 2 ml syringe to unblock a clotted cannula (basic physics).
- If the patient is going to ICU/HDU you will never have enough venous access – always insert a spare cannula.
- Over flat areas of skin, such as the forearm, a slight upward bend of the cannula makes insertion easier (if the bend is excessive the needle will not come out!).
- Never try to apply adhesive dressing with your gloves on.
- If you think that you might need invasive monitoring, you will. Insert the cannula.
- If you have to cannulate the brachial artery, rather than the radial artery, use a 5 cm long cannula rather than 3 cm to prevent kinking when the elbow flexes.
- If you are struggling to find a vein in the antecubital fossa, externally rotate the arm and look carefully on the medial aspect of the forearm.
- Twice the diameter of a cannula gives 16 times the flow rate. Never use a venous cannula smaller than 16 gauge.
- Never say to the patient ‘just a little prick’ before inserting a cannula – you are likely to be told that is exactly what you are!

- Never anaesthetise a woman of child-bearing age without inserting a large-bore venous cannula (? ectopic pregnancy).
- Put blood bags into pressure infusers with the label furthest from you. When you can see the label the bag is empty.

Monitoring and Equipment

- Never use a ventilator, anaesthetic machine or any equipment with which you are unfamiliar. This is an absolute rule after hours.
- If you have a problem with the ventilator or breathing system that you cannot instantly identify and correct, change to a simple circuit and hand-ventilate the patient.
- Know where the defibrillator is kept in theatre and how it works.
- If a monitor gives an abnormal value, such as low oxygen saturation, check the patient and then the equipment.
- Make sure that you are not the only sucker in the anaesthetic room or theatre.
- An AMBU bag is invaluable in a power failure!

Regional Anaesthesia

- Never persuade an unwilling patient to have regional anaesthesia.
- If you need midazolam or fentanyl with your local block, it has failed.
- When inserting an epidural catheter, thread it straight from the sterile bag to prevent it uncoiling and touching something unsterile.
- It is often easier in the elderly to insert the epidural or spinal with the patient in a sitting position, leaning forward.
- Try the L5/S1 interspace when you have failed higher up the spine.
- If it is difficult to thread an epidural catheter through the needle, withdraw the needle very slightly.
- Never trust anyone else's epidural – you don't know where it is sited! Aspirate the catheter.
- Just because there is a nerve you don't have to block it

Drugs

- All 1 ml ampoules look the same – check very carefully.
- Always label all syringes.
- Atropine and adrenaline (epinephrine) are often stored next to each other.
- Suxamethonium can easily be given in error for all drugs found in 2 ml syringes.
- Put the label on the syringe at the volume you fill it to. You can check later how much you have given.
- Intravenous drugs go into veins, so colour-code the three-way taps. Blue for venous, red for arterial. If the cannula has a filter it is in the epidural space!
- For a rapid sequence induction always have two doses of NMBD ready in case one goes over the floor/ceiling etc.

Conclusion

Anaesthesia is fun. We still enjoy it after a total of more than 80 years' practice. Remember:

Be kind – patients are very vulnerable.

Be prepared – plan your anaesthetic.

Be professional – try to emulate Humphrey Bogart's definition of a professional as somebody who can still give their best performance when they feel least like it!

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